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PRACTICAL

MEDICAL CHEMISTRY,

FOR

PHYSICIANS AND STUDENTS.

BY

CHARLES PLATT,
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AND

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SIXTH EDITION
REWRITTEN AND ENLARGED.

PHILADELPHIA:
JOHN JOS. McVEY,
1911

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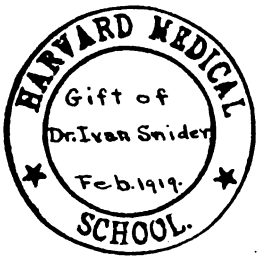

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PREFACE TO THE SIXTH EDITION.

THE success of preceding editions has rendered any material alteration in plan unadvisable. In the present rewriting, however, the book has been completely revised and its scope enlarged by several added chapters, as well as by numerous minor additions throughout. Statements and tests already presented have been critically examined and, where necessary, simplified or amplified as seemed desirable. Much new descriptive matter relative to substances of medical interest has been inserted. It has been the aim of the authors to prepare a text-book suitable for physicians or for use in any college; one which shall contain the essentials of medical chemistry and yet shall permit of latitude on the part of the teacher in presenting the subject to his classes.

As it now stands the book presents the following: A chapter of Chemical Definitions and Laws, a synopsis of the Non-metals, their properties and compounds, the same of the Metals, an outline of Qualitative Analysis including schemes for both simple salts and complex mixtures, tests for the Acids, tests for the Alkaloids, directions for Toxicological Examinations, and, finally, in Part I., a chapter on Quantitative Analysis. Part II., covering the Chemistry of the Carbon Compounds, includes a general outline of the Hydrocarbons and their Derivatives, with a more detailed description of the Fats, the Carbohydrates, the Proteins, and the Ferments. Part III. treats of subjects of especial physiologic and clinical interest, including chapters on the Chemistry of the Body, Food, Digestion, the Saliva, the Gastric Fluid, the Pancreatic Fluid, the Bile, the Intestinal Fluid, the Urine, the Perspiratory Fluid, the Feces, the Blood, Milk, and Water. The chapter on Urine Analysis is complete, covering all the essentials for a thorough examination, together with suggestions as to the clinical significance of the results obtained. The Appendix, together with Tables of Weights and Measures, contains directions for the preparation of

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Percentage Solutions, a list of the Acid Radicals, a table of the Common Salts, arranged according to solubility, a list of Reagents, with formulæ and methods of preparation, and a complete list of the Poisons, with symptoms and treatment.

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PART I.

INORGANIC CHEMISTRY,

QUALITATIVE AND QUANTITATIVE ANALYSIS.

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TABLE OF THE ELEMENTS.

Names.	Symbols.	Atomic Weights.		Names.	Symbols.	Atomic Weights.	
		U.S.P.*	B. P.†			U.S.P.*	B. P.†
Aluminum	Al	26.9	26.90	Neodymium	Nd	142.5	
Antimony	Sb	119.3	119.00	Neon	Ne	19.9	
Argon	Ar	39.6		Nickel	Ni	58.3	
Arsenic	As	74.4	74.50	Nitrogen	N	13.93	13.94
Barium	Ba	136.4	136.40	Osmium	Os	189.6	
Bismuth	Bi	206.9	207.30	Oxygen	O	15.88	15.88
Boron	B	10.9	10.85	Palladium	Pd	105.7	
Bromine	Br	79.36	79.35	Phosphorus	P	30.77	30.80
Cadmium	Cd	111.6		Platinum	Pt	193.3	193.30
Cæsium	Cs	131.9		Potassium	K	38.86	38.83
Calcium	Ca	39.8	39.71	Praseodymium ‖	Pr	139.4	
Carbon	C	11.91	11.91	Radium	Ra	223.	
Cerium	Ce	139.2	139.20	Rhodium	Rh	102.2	
Chlorine	Cl	35.18	35.19	Rubidium	Rb	84.8	
Chromium	Cr	51.7	51.74	Ruthenium	Ru	100.9	
Cobalt	Co	58.56		Samarium	Sm	148.9	
Columbium ‡	Cb	93.3		Scandium	Sc	43.8	
Copper	Cu	63.1	63.12	Selenium	Se	78.6	
Erbium	Er	164.8		Silicon	Si	28.2	
Fluorine	F	18.9		Silver	Ag	107.12	107.11
Gadolinium	Gd	155.		Sodium	Na	22.88	22.88
Gallium	Ga	69.5		Strontium	Sr	86.94	
Germanium	Ge	71.9		Sulphur	S	31.83	31.82
Glucinum ⁋	Gl	9.03		Tantalum	Ta	181.6	
Gold	Au	195.7	195.70	Tellurium	Te	126.6	
Helium	He	4.		Terbium	Tb	158.8	
Hydrogen	H	1.000	1.00	Thallium	Tl	202.6	
Indium	In	113.1		Thorium	Th	230.8	
Iodine	I	125.90	125.90	Thulium	Tu	169.7	
Iridium	Ir	191.5		Tin	Sn	118.1	118.20
Iron	Fe	55.5	55.60	Titanium	Ti	47.7	
Krypton	Kr	81.2		Tungsten	W	182.6	
Lanthanum	La	137.9		Uranium	U	236.7	
Lead	Pb	205.35	205.35	Vanadium	V	50.8	
Lithium	Li	6.98	6.97	Xenon	Xe	127.	
Magnesium	Mg	24.18	24.18	Ytterbium	Yb	171.7	
Manganese	Mn	54.6	54.52	Yttrium	Yt	88.3	
Mercury	Hg	198.5	198.80	Zinc	Zn	64.9	64.91
Molybdenum	Mo	95.3		Zirconium	Zr	89.9	

* Atomic weights adopted for the United States Pharmacopœia, 1905.

† British Pharmacopœia, 1898, issue of 1903.

‡ Also known as Niobium, Nb.

⁋ Also known as Beryllium, Be.

‖ Also known as Didymium, Di.

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DEFINITIONS AND LAWS.

Matter is that which occupies space and has weight.

Chemistry is that science which treats of the composition of matter and of the changes which this composition may undergo.

A *Chemical Element* is a single kind of matter which cannot, by known means, be resolved into different kinds. There are about 80 elements; some are solid, some liquid, and some gaseous. Thus Sulphur, Carbon, Arsenic, Silver, Chlorine and Nitrogen are chemical elements because none of these substances have ever been divided into different kinds of matter.

A *Chemical Compound* is a definite combination of two or more elements held together by a force called *chemism*. The properties of a chemical compound are usually different from those of its constituents.

A *Chemical Change*, or chemical reaction, occurs only when there is some rearrangement of the elements in a compound, or when the union of one or more elements takes place.

In a *Mixture* the ingredients may be present in any proportion. The properties of a mixture are, in general, the sum of the properties of its ingredients.

Laws Governing Chemical Combination.

Law of Indestructibility of Matter. Matter can neither be destroyed nor created; therefore the sum of the products of a chemical reaction must be equal to the sum of the factors entering into that reaction.

Law of Definite or Constant Proportions. The same chemical compound is composed always of the same elements, united always in the same proportion, *e. g.*, water is composed of hydrogen and oxygen united always in the proportion of 2 parts by weight of hydrogen with 16 parts by weight of oxygen.

Law of Multiple Proportions. When two elements combine in more than one proportion the varying quantities of the one com-

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bining with a fixed quantity of the other bear a simple relation to each other. *E. g.*, in water, 16 parts of oxygen combine with 2 parts of hydrogen; in hydrogen dioxide, 32 parts of oxygen combine with 2 parts of hydrogen. The ratio between the two quantities of oxygen in these two compounds, then, is 16 to 32, or 1 to 2.

Law of Gaseous Volumes. When two gases combine, the volumes of the gases which enter into the combination bear a simple relation to each other and to the volume of the compound gas produced. *E. g.*, one volume of hydrogen combines with 1 volume of chlorine to make 2 volumes of hydrochloric acid gas. Three volumes of hydrogen combine with 1 volume of nitrogen to make 2 volumes of ammonia gas.

An *Atom* is the smallest particle of matter capable of entering into a chemical combination. Physical chemistry has shown that atoms consist of still smaller particles called emanations. From 100,000 to 350,000 of these compose a single atom. These particles are now considered as positive and negative. It has been suggested that the excess of either kind determines the nature of the element and also its combining power or valence.

A *Molecule* is the smallest particle into which matter can be divided without altering its characteristic properties.

The *Atomic weight* of an element is the relative weight of one atom of that element as compared with the weight of one atom of another element. Hydrogen is usually chosen as the standard for comparison. Often the atomic weight of oxygen is considered exactly 16 and the atomic weights of the other elements computed to corresponding values.

The *Molecular weight* is the sum of the atomic weights of all the atoms comprising a molecule.

AVOGADRO'S HYPOTHESIS. *Equal volumes of all gases at the same temperature and pressure contain an equal number of molecules.* This hypothesis is of great value, as the molecular weight of any gas can be found by comparing its weight with the weight of an equal volume of hydrogen at the same temperature and pressure. 22.25* liters of any gas at 0° C. and 760 m.m. pressure will weigh its molecular weight expressed in grammes.

Valence (Valency or Quantivalence) is that property of an atom

* Metric weights and measures are used extensively in this book, hence the student is requested to make himself familiar with these units. See Appendix for tables.

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which enables it to hold in combination a certain number of other atoms. The valence of an atom is commonly measured by the number of atoms of hydrogen with which it can combine, or which it can replace in a molecule. Elements with atoms having a valence of one are called *Monads*, or are said to be univalent. Those with a valence of two are *Dyads*, or bivalent; of three, are *Triads*, or trivalent; of four, are *Tetrads*, or quadrivalent; of five, are *Pentads*, or quinquivalent; of six, are *Hexads*, or sexivalent, etc.

In chemical combinations one monad will combine with, or replace, one monad; one dyad will combine with, or replace, one dyad or two monads, etc.

Valence must not be confused with chemism. Valence is a relative measure of the ability a certain atom has of holding in chemical combination other atoms. One atom of hydrogen will combine with one atom of chlorine, calcium with two, aluminium with three and carbon with four. The valence of calcium is therefore said to be two, aluminium three and carbon four, for each atom of calcium, aluminium and carbon will combine respectively with two, three and four times as much chlorine as will one atom of hydrogen. Some elements have more than one valence, but few have more than two.

Chemism refers more particularly to the persistency, force or energy with which the atoms of one element combine with those of another and not to the measure of the amounts entering into chemical combination.

Chemical Symbols and Formulæ.

Symbols are used to express atoms. H means one atom of hydrogen, Cl one atom of chlorine, Fe one atom of iron.

Formulæ are expressions of the composition of molecules by use of symbols and show the number of atoms of each kind present; thus H_2SO_4 represents one molecule of the chemical compound known as sulphuric acid, which contains two atoms of hydrogen, one atom of sulphur and four atoms of oxygen in each molecule. $3H_2SO_4$ represents three molecules of sulphuric acid.

There are three kinds of formulæ, Empirical, Rational, and Graphic or Structural.

An Empirical formula represents the elements present in a compound and the relative proportion of each, but does not show

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the classification of the compound by separating the symbols into groups.

C_2H_6O is the empirical formula for ethyl alcohol.

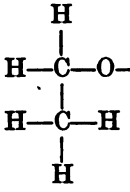
H_2SO_4 is the empirical formula for sulphuric acid.

A RATIONAL FORMULA is one which shows the classification of the compound by separating its atoms into groups.

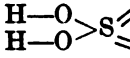
C_2H_5OH is a rational formula for ethyl alcohol.

$(OH)_2SO_2$ is a rational formula for sulphuric acid.

A GRAPHIC or STRUCTURAL FORMULA is one which attempts to diagrammatically show the exact way in which the atoms of a compound are joined together in accordance with the valence and peculiarity of each element.



is a graphic or structural formula for ethyl alcohol, and shows how the atoms of carbon having a valence of four may be joined with six atoms of hydrogen each having a valence of one and one atom of oxygen having a valence of two.



is a graphic or structural formula for sulphuric acid.

PERCENTAGE COMPOSITION.

The percentage of any element in a compound may be calculated from the formula of the compound as follows: Multiply the atomic weight of the element by the number of its atoms present, divide the result by the molecular weight of the compound, and finally, multiply by 100.

The empirical formula of a compound may be calculated from its percentage composition as follows: Divide the percentage of each element present by its atomic weight, and use the quotients so obtained as exponents for the respective symbols in the formula. Reduce to simplest therms.

To obtain the molecular formula the molecular weight of the compound must be known; that one among the possible empirical formulæ which shows this same molecular weight is, then, the molecular formula.

Isomerism. Substances having the same percentage composition

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but different properties are said to be *isomeric.* If they have the same percentage composition and also the same molecular weight, they are *metameric, e. g.*, Ammonium isocyanate, $(NH_4)CNO$, and Urea, $CO(NH_2)_2$. If they have the same percentage composition and different molecular weights, they are *polymeric, e. g.*, Formaldehyde, CH_2O, and Glucose, $C_6H_{12}O_6$.

A Radical is an atom or group of atoms which may enter into chemical combination but is incapable of existing alone. E.g., Atomic oxygen, O; the hydroxyl group, OH; the sulphate group, SO_4.

A Chemical Equation is a symbolic expression in chemical notation designed to show the changes which take place in a chemical reaction. Many intermediate changes usually take place before the final arrangement represented is reached. This diagrammatic scheme must be in accordance with the actual transformation and comply with the law of conservation of matter by having the same number of atoms of any one kind on each side of the sign of equality. BALANCING equations consists of adjusting the number of atoms so that the same number of every kind shall be on each side of the sign of equality.

The compounds represented by the equation must be those actually formed in the reaction.

Chemical reactions may take place in four ways.

1st.—*By synthesis* or *building up.* Oxygen plus hydrogen forms water.

$$O + H_2 = H_2O.$$

2d.—*By analysis or breaking down.* Mercuric oxide heated forms mercury and oxygen.

$$HgO + \text{heat} = Hg + O.$$

3d.—*By substitution.* Zinc plus hydrochloric acid forms zinc chloride and hydrogen.

$$Zn + 2\,HCl = ZnCl_2 + H_2.$$

In this reaction it is easily seen that the zinc replaces or is substituted for the hydrogen in hydrochloric acid.

4th.—*By double decomposition.* Silver nitrate plus hydrochloric acid forms silver chloride and nitric acid.

$$AgNO_3 + HCl = AgCl + HNO_3.$$

In this illustration atoms of silver and hydrogen change places.

A precipitate is any kind of material thrown out of solution.

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Precipitation is frequently caused in chemical reactions by the formation of an insoluble compound.

An OXIDIZING agent is one that will furnish oxygen either directly or indirectly for a chemical change. Potassium chlorate and nitric acid are good oxidizing agents because they will often give up a portion of their oxygen. Many oxidizing agents have the power to increase the valency of elements.

A REDUCING agent is one that readily combines with, and often removes the oxygen from other compounds. It often reduces the valency of an element.

ACIDS, BASES AND SALTS.

An ACID is a chemical compound containing hydrogen, part or all of which is capable of being replaced by a metallic element.

Substances which will replace hydrogen in an acid are called *bases*. All metals are bases but all bases are not metals; thus the compound ammonium hydroxide will combine with an acid, the ammonium radical replacing the available hydrogen. The product formed by replacing part or all of the hydrogen of an acid is called a *salt*.

NOMENCLATURE OF ACIDS.

The acids are classified as *Hydracids*, those containing no oxygen, and *Oxyacids*, those which contain oxygen. All hydracids have in their name the prefix "hydro" and the suffix "ic." The names of the oxyacids end in "ous," or "ic," the latter termination expressing the presence of relatively more oxygen than the former. An acid with less oxygen than is contained in the "ous" acid is written with the prefix "hypo," together with the suffix "ous." An acid with more oxygen than is contained in the "ic" acid is written with the prefix "per" and suffix "ic;" thus: Hypochlorous acid, $HClO$, Chlorous acid, $HClO_2$, Chloric acid, $HClO_3$, Perchloric acid, $HClO_4$. Acids are also classified as *Monobasic*, *Dibasic*, *Tribasic*, *etc.*, according to the number of replaceable hydrogen atoms contained in a molecule.

A BASE is the chemical opposite of an acid being capable of combining with the acid by replacing part or all of its hydrogen. This reaction is termed *neutralization* and will usually take place when acids are brought in contact with bases.

A SALT is a compound formed from an acid by substituting a metal or basic radical for part or all of the replaceable hydrogen of the acid.

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NOMENCLATURE OF SALTS.

A *Normal Salt* is one formed from an acid by substituting a metal or basic radical for all of the replaceable hydrogen of the acid. E. g., from H_2SO_4, the normal salt, Na_2SO_4.

An *Acid Salt* is one formed from an acid by substituting a metal or basic radical for part of the replaceable hydrogen of the acid. *E. g.*, from H_2SO_4, the acid salt, $NaHSO_4$.

A *Double Salt* is a salt containing two different metals or basic radicals in its molecule. *E. g.*, from $H_2C_4H_4O_6$, the double salt, $KNaC_4H_4O_6$.

A *Basic Salt*, also known as an *oxy-* or a *sub-* salt, is a compound of a normal salt with the corresponding metallic oxide or hydroxide—it is intermediate in character between a true base and a normal salt, and there is not sufficient acid radical combined to form the normal salt. *E. g.*, the normal salt, $Bi(NO_3)_3$; the basic salt, $Bi(OH)_2NO_3$; the base, $Bi(OH)_3$.

The names of salts formed from hydracids have the suffix "ide;" those formed from oxyacids have the suffix "ite," or "ate," the former being derived from "ous" acids, the latter from "ic" acids. Thus: Hydrosulphuric acid, H_2S, the sodium salt, Sodium sulphide, Na_2S; Sulphurous acid, H_2SO_3, the salt, Sodium sulphite, Na_2SO_3; Sulphuric acid, H_2SO_4, the salt, Sodium sulphate, Na_2SO_4.

The terminations "ous" and "ic" may be used, also, to distinguish between different combinations of the same elements—the "ous" indicating the lower valence (real or apparent) of the positive element. *E. g.*, Mercurous chloride, HgCl; Mercuric chloride, $HgCl_2$. Ferrous sulphate, $FeSO_4$; Ferric sulphate, $Fe_2(SO_4)_3$. Sulphurous oxide, SO_2; sulphuric oxide, SO_3. Ferrous chloride, $FeCl_2$; Ferric chloride, $FeCl_3$.

Again the same distinction may be made by the numerical prefixes, mono-, di- (or bi-), tri-, tetra-, penta-, etc., these being joined to the name of the more negative element. *E. g.*, Sulphur dioxide, SO_2; Sulphur trioxide, SO_3.

The older prefixes "sub-" and "proto-" correspond generally with the suffix "ous"; the prefixes, "sesqui-" and "per-" with the suffix "ic." *E. g.*, Mercurous chloride has been called protochloride of mercury; $FeCl_2$, protochloride of iron, and $FeCl_3$, sesquichloride or perchloride of iron.

Anhydrides are chemical compounds which will unite with

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water and form an acid. *E. g.*, Sulphur trioxide (SO_3); with water it forms Sulphuric acid, H_2SO_4. This term must not be confused with the term *anhydrous*, which refers to chemical compounds not holding water in combination.

Many compounds are combined with water, so loosely, that it may be removed, without decomposition of the compound, by heating. Water in this combination is often responsible for the crystalline structure, and is then called *water of crystallization.*

When the water is combined more intimately and cannot be removed without the decomposition of the compound, it is called *water of constitution.*

Crystals are substances possessing a definite internal arrangement of molecules, this arrangement, under favorable conditions, becoming evident in regularity of external form.

Amorphous or *colloidal substances* are those possessing no regularity of molecular arrangement.

Substances are said to be *deliquescent* when they become damp or take up water on exposure to the atmosphere.

Efflorescent substances give up water when exposed to the atmosphere.

Allotropism is that property by virtue of which an element may assume different forms, depending generally upon the number of atoms grouped in the molecule. *E. g.*, Oxygen gas, O_2; Ozone, O_3.

Osmosis or *Dialysis* is the diffusion through membranes of substances in solution. *Colloids* are substances which do not thus readily diffuse through membranes, *Crystalloids* are substances which do.

Electrolysis is the decomposition of a chemical compound, in the fluid state, by the passage of the electric current; the solution or fluid so decomposed is known as an *Electrolyte.* The terminations of the electric wires are called *electrodes*, and are known as positive and negative.

In a zinc and carbon battery the wire from the carbon is the positive electrode, and the current is considered as passing from the positive to the negative electrode.

Ions are the portions of a chemical compound into which it is separated by the electric current. They are of two kinds, negative and positive.

The negative ions or *anions*, are attracted to the positive electrode, the anode; the positive ions or *cations* to the negative electrode, the cathode.

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Classification of Elements:—By electrolysis it is possible to classify the elements into two groups—electro-positive and electro-negative.

The elements are classified scientifically according to their atomic weights (Mendelejeff's Periodic System), it being found that, so arranged, elements having similar properties group themselves at regular intervals in the series.

For practical, elementary, and laboratory purposes, however, it is convenient to retain the old division into Non-metals and Metals, and to classify the metals into groups according to their behavior with certain reagents. Following this plan, it will be noticed that Arsenic, Antimony, and Bismuth, usually regarded as non-metals, are here placed with the metals in the same class with Copper, Tin, Mercury and Cadmium.

It is impossible to differentiate always between the two classes, of Metals and Non-metals; we may, however, define the typical member of each class as follows:

A *Metal* is an electro-positive element, uniting with oxygen to form a basic oxide.

A *Non-metal* is an electro-negative element, uniting with oxygen to form an acid oxide.

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THE NON-METALS.

Hydrogen.

Symbol, H. Atomic weight, 1. Valence, I.

Occurrence. In *free state*, comparatively rare, but found in intestinal gases, and elsewhere among products of organic decomposition. In *combination*, abundantly, in water, in ammonium compounds, acids, and in most organic matter.

Prepared. 1.) By the action of zinc on sulphuric acid.

$$Zn + H_2SO_4 = H_2 + ZnSO_4.$$

2.) By action of sodium on water.

$$Na + 2H_2O = H_2 + 2NaOH.$$

Properties. Colorless, odorless, tasteless gas. Lightest substance known, 14.4 times lighter than air. 1000 c.c. weighs 0.0896 Gm. at 0° C. and 760 m.m. pressure. Is inflammable, burning with a pale bluish flame. The mixture with air is explosive.

Chemically, hydrogen has a strong affinity for oxygen, and is useful therefore as a *reducing* or *deoxidizing* agent.

It is valuable, because of the intense heat generated by its union with oxygen, in the oxy-hydrogen blow-pipe; because of its affinity for oxygen, as a reducing agent; and, because of its lightness, for filling baloons, etc.

Oxygen.

Symbol, O. Atomic weight, 15.88. Valence, II.

Occurrence. In *free state*, about one-fifth of the atmosphere. In *combination*, in water (eight-ninths), and in nearly all animal, vegetable, and mineral compounds.

Prepared. 1.) By heating mercuric oxide.

$$2HgO + \text{heat} = Hg_2 + O_2.$$

2.) By heating potassium chlorate, best after addition of a little manganese dioxide.

$$2KClO_3 + \text{heat} = 3O_2 + 2KCl.$$

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Properties. Colorless, odorless, tasteless gas, a little heavier than air, only slightly soluble in water. 1000 c.c. weighs 1.43 Gm. at 0° C. and 760 m.m. pressure. It is incombustible, but is a supporter of combustion. It unites readily with most other elements, forming oxides; with non-metals, acid oxides, with metals, basic oxides.

OZONE, O_3 (Oxygen, O_2). *Prepared.* 1.) By moistening a mixture of potassium permanganate and barium dioxide with sulphuric acid. 2.) By the slow oxidation of moist phosphorus. 3.) By electric discharge through air or oxygen. 4.) By plunging a red-hot glass rod into a bottle filled with air and ether vapor.

Properties. A gas like oxygen but heavier, with characteristic odor. A strong oxidizing agent. Soluble in oils. A paper impregnated with starch and potassium iodide becomes blue when exposed to the gas.

HYDROGEN MONOXIDE, H_2O. (Water.) May be made by (1) burning hydrogen in air, (2) by exploding a mixture of hydrogen and oxygen, (3) by the reaction between a base and an acid. It may be decomposed by high temperatures and by electrolysis.

HYDROGEN DIOXIDE, H_2O_2. *Prepared.* By the action of an acid on barium dioxide.

$$BaO_2 + H_2SO_4 = H_2O_2 + BaSO_4.$$

Properties. A colorless liquid without odor, but with a characteristic taste. The strong solutions quickly decompose, the dilute solutions are more stable. The usual strength is a three per cent. by weight solution, giving off ten volumes of available oxygen.

Test.—To 10 c.c. of water in a test tube add 1 drop of potassium chromate, 10 drops of dilute sulphuric acid, a few c.c. of ether, and then a few drops of the hydrogen dioxide, or of the solution to be tested. The presence of the dioxide is indicated by the production of a blue color.

Assay. The strength of a sample may be determined by adding tenth-normal potassium permanganate to one cubic centimeter diluted with about 25 c.c. of water and 5 c.c. of 10 per cent sulphuric acid until a permanent pink color is produced. Each cubic centimeter of the potassium permanganate is equivalent to 0.001688 of hydrogen dioxide.

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NITROGEN.

Symbol, N. Atomic weight, 13 93. Usual valence, III and V.

Occurrence. In the *free state* in the atmosphere, in *combination* in some mineral compounds and in many animal and vegetable compounds.

Prepared. 1.) By passing air over incandescent copper, the metal uniting with the oxygen present. 2.) By heating ammonium nitrite.

$$NH_4NO_2 + \text{heat} = N_2 + 2H_2O.$$

Properties. A colorless, odorless, tasteless gas, a little lighter than air, incombustible, a non-supporter of combustion, does not support life, is not poisonous.

ATMOSPHERE. The essential ingredients of the atmosphere are Nitrogen, about 77.2 per cent.; Oxygen, 20.6 per cent.; Carbon dioxide, 0.03–0.04 per cent.; Aqueous vapor, 0.5–1.4 per cent. Argon, Helium, etc., formerly included with the Nitrogen, together make up a fraction of one per cent. Compounds of Nitrogen, of Sulphur, and of Carbon, are present in variable traces and may be regarded as accidental ingredients.

The carbon dioxide and water may be estimated by passing a measured volume of air through two weighed tubes; the first, containing calcium chloride, absorbs water, the second, containing potassium hydroxide, absorbs carbon dioxide. From the increase in weight of the tubes the amounts of carbon dioxide and water in the air may be calculated.

AMMONIA, NH_3. *Occurrence.* Produced in the decomposition of nitrogenous organic matter.

Prepared. Commercially from the ammoniacal liquor obtained in the manufacture of coal-gas. It may be made: 1.) By mixing equal parts of ammonium chloride and calcium hydroxide, and heating. 2.) By treating ammonium chloride, dry, or in solution, with sodium hydroxide. 3.) By boiling a solution of ammonium hydroxide.

$$NH_4Cl + NaOH = NH_3 + NaCl + H_2O.$$

Properties. A colorless gas with characteristic odor; will burn in pure oxygen, but not in air; very soluble in water, the solution being known as ammonium hydroxide. Ammonia water, U. S. P. = 10 per cent. solution of the gas. The stronger am-

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monia water, U. S. P.* = 28 per cent. solution. The radical, NH_4, AMMONIUM, forms compounds similar to those of the alkali metals. For ammonium compounds and for tests, see Index.

NITROGEN MONOXIDE, N_2O. Nitrous oxide or Laughing Gas. *Prepared* by heating ammonium nitrate.

$$NH_4NO_3 + \text{heat} = N_2O + H_2O.$$

Properties. A colorless, odorless gas, with a faint sweetish taste, producing anesthesia when inhaled.

NITROGEN DIOXIDE or NITRIC OXIDE, N_2O_2 or 2NO. A colorless gas. May be prepared by treating copper with nitric acid.

$$3Cu + 8HNO_3 = 2NO + 3Cu(NO_3)_2 + H_2O.$$

NITROGEN TRIOXIDE, N_2O_3. (Nitrous anhydride.) A blue liquid with low boiling-point, with water forming NITROUS ACID, HNO_2, an unstable substance, important only because of its salts, the nitrites, these being valuable reducing agents. For tests, see Index.

NITROGEN TETROXIDE or NITROGEN PEROXIDE, N_2O_4. A colorless liquid at low temperatures; at higher temperatures a reddish-brown gas $2NO_2$.

NITROGEN PENTOXIDE, N_2O_5. (Nitric anhydride.) A crystalline substance forming, with water, nitric acid.

NITRIC ACID, HNO_3. Made practically by treating sodium nitrate with sulphuric acid.

$$2NaNO_3 + H_2SO_4 = 2HNO_3 + Na_2SO_4.$$

It is a colorless, fuming liquid, turns yellow on exposure to light and air, attacks organic matter, corrodes the skin and turns it yellow, and dissolves most metals, forming nitrates.

Two strengths are in common use, the concentrated containing about 68 per cent. and the dilute containing 10 per cent. acid. For tests, see Index.

THE HALOGEN ELEMENTS.

FLUORINE.

Symbol, F. Atomic weight, 18.9. Valence, I.

Fluorine is rare in the free state. The acid of fluorine, HYDROFLUORIC ACID, HF, may be made by treating powdered calcium fluoride with sulphuric acid.

*U S. P. is an abbreviation for United States Pharmacopœia. Preparations contained in this book are said to be "official." Reference is made to the eighth decennial revision, which is now a legal standard.

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$$CaF_2 + H_2SO_4 = 2HF + CaSO_4.$$

It is a powerful corrosive, attacks glass, and is used in the etching of glass. Vapors are dangerous.

Chlorine.

Symbol, Cl. Atomic weight, 35.18. Valence, I.

Prepared. 1.) By heating hydrochloric acid with manganese dioxide.

$$4HCl + MnO_2 = Cl_2 + MnCl_2 + 2H_2O.$$

2.) By heating manganese dioxide, sodium chloride and sulphuric acid.

$$MnO_2 + 2NaCl + 2H_2SO_4 = Cl_2 + Na_2SO_4 + MnSO_4 + 2H_2O.$$

Properties. A yellowish-green gas, with suffocating odor, soluble in water ("chlorine water"). Liquor Chlori Compositus, U. S. P. contains about 0.4 per cent. chlorine with oxides of chlorine and potassium chloride.

Chlorine mixed with hydrogen explodes when exposed to the light. Acts as an oxidizing agent and bleach.

Hydrochloric Acid is prepared by the action of sulphuric acid on sodium chloride.

$$2NaCl + H_2SO_4 = 2HCl + Na_2SO_4.$$

It is a colorless, irrespirable gas, very soluble in water; it dissolves many metals, forming chlorides. The commercial "muriatic acid" is generally yellow from presence of ferric chloride. U. S. P. acid, 31.9 per cent. by weight, the dilute acid, 10 per cent. Other acids of chlorine are Hypochlorous Acid, $HClO$; Chlorous Acid, $HClO_2$; Chloric Acid, $HClO_3$; Perchloric Acid, $HClO_4$. For tests, see Index.

Bromine.

Symbol, Br. Atomic weight, 79.36. Valence, I.

Prepared, by the action of sulphuric acid and manganese dioxide on potassium bromide.

Properties. A dark reddish-brown, volatile liquid, giving off pungent, irritating fumes. It is soluble in twenty-eight parts of water, forming "bromine water." Soluble in alcohol and in ether.

Hydrobromic Acid may be made by the action of sulphuric acid on potassium bromide. It is similar, chemically, to hydro-

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chloric acid. U. S. P. acid, a 10 per cent. solution, a clear, colorless liquid. For tests, see Index.

Iodine.

Symbol, I. Atomic weight, 125.90. Valence, I.

Prepared, by the action of sulphuric acid and manganese dioxide on potassium iodide.

Properties. Blue-black, friable, rhombic plates, volatile, giving off violet-colored vapors with a pungent odor. It is soluble in 5000 parts of pure water, and in 10 parts of alcohol. Soluble in water containing potassium iodide, and soluble in chloroform. With starch solution, gives a blue color.

Hydriodic Acid may be made by the action of sulphuric acid on potassium iodide. It is similar, chemically, to hydrochloric acid. U. S. P. acid, a 10 per cent. solution, clear, colorless liquid. It soon becomes dark on exposure to the air. For tests, see Index.

Phosphorus.

Symbol, P. Atomic weight, 30.77. Valence, III, V.

Occurrence. In nature chiefly as tricalcic phosphate.

Prepared, from calcium phosphate, $Ca_3(PO_4)_2$; this substance is converted into phosphoric acid by treatment with H_2SO_4 and the acid is then reduced by heating with carbon.

$$Ca_3(PO_4)_2 + 3H_2SO_4 = 2H_3PO_4 + 3CaSO_4.$$
$$4H_3PO_4 + C = P_4 + CO + H.$$

Properties. There are two allotropic forms, yellow and red. Ordinary phosphorus is a waxy, yellow, semi-transparent solid with characteristic odor, giving off luminous fumes. It oxidizes on exposure to air, is kept under water, is soluble in carbon disulphide and in oils, and is strongly poisonous.

Red or Amorphous Phosphorus is made by heating the ordinary variety for several days in a closed tube. It is a red, amorphous powder, does not give off fumes, is not luminous in the dark, is not soluble in carbon disulphide, nor in oils, and is not poisonous.

Phosphoric Acid, H_3PO_4, a colorless syrupy liquid. U. S. P. 85 per cent.; dilute, 10 per cent. Hypophosphorous Acid, H_3PO_2, U. S. P. 30 per cent. and 10 per cent. For tests, see Index.

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SULPHUR.

Symbol, S. Atomic weight, 31.83. Valence, II, IV.

Occurrence. *Free*, in volcanic regions. *Combined*, in form of sulphates and sulphides.

Prepared, by refining the crude sulphur of nature.

Properties. Ordinary sulphur is a yellow, brittle solid, or a fine yellow powder. It melts when heated, and, in the air, burns to sulphur dioxide.

Sublimed Sulphur, U. S. P. (Flowers of Sulphur.) A fine yellow powder, with a slight characteristic odor and faint acid taste. Soluble in carbon disulphide, slightly soluble in absolute alcohol, more soluble in benzin, benzene, turpentine, ether, and chloroform.

Washed Sulphur, U. S. P. (Sulphur lotum.) Obtained by washing sublimed sulphur with ammonia water.

Precipitated Sulphur, U. S. P. Made by boiling together lime and sulphur in water and then decomposing the compound produced, by addition of hydrochloric acid.

HYDROGEN SULPHIDE, or Hydrosulphuric acid, H_2S, is prepared by the action of an acid, preferably hydrochloric acid, on ferrous sulphide. It is an inflammable gas, with characteristic odor, soluble in water, used in chemical analysis.

$$FeS + 2HCl = H_2S + FeCl_2.$$

SULPHUR DIOXIDE, SO_2. *Prepared*, by burning Sulphur.

Properties. It is a colorless gas with suffocating odor; it is soluble in water, forming SULPHUROUS ACID, H_2SO_3. The U. S. P. acid is a 6 per cent. by weight solution of SO_2. It is a colorless liquid with odor of burning sulphur. For tests, see Index.

SULPHUR TRIOXIDE, SO_3. *Prepared*, by oxidation of sulphur dioxide, is generally in crystal form. Dissolved in water it gives SULPHURIC ACID, H_2SO_4. The latter is a heavy corrosive liquid, colorless when pure, but often brown from presence of carbon. It has a strong affinity for water, the union of the two being accompanied by the evolution of heat. The U. S. P. acid is a 92.5 per cent. solution, the dilute acid, a 10 per cent. solution. For tests, see Index.

SULPHUR IODIDE, U. S. P. Occurs in grayish-black, brittle masses with the odor of iodine.

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CARBON.

Symbol, C. Atomic weight, 11.91. Valence, IV.

Occurs in nature in three allotropic forms, the clear isometric crystal diamond, the black hexagonal crystalline graphite, and the amorphous variety as found in soot, charcoal, etc. Carbon resists the action of most ordinary reagents, but at high temperatures it has a strong affinity for oxygen and is, therefore, a valuable reducing agent. U. S. P. preparations: *Carbo ligni*, wood charcoal; *Carbo animalis*, animal charcoal, containing about 85 per cent. of ash; and *Carbo animalis purificatus*, the purified animal charcoal, obtained by washing the ordinary animal charcoal with hydrochloric acid, and containing about 4 per cent. ash.

CARBON MONOXIDE, CO (Carbonic oxide). *Prepared.* 1.) By burning carbon with an insufficient supply of oxygen. 2.) By warming a mixture of 1 part crystalline potassium ferrocyanide and 10 parts of strong sulphuric acid. 3.) By passing CO_2, or by passing steam (H_2O), over red-hot carbon.

Properties. A colorless, odorless gas, very slightly soluble in water, a non-supporter of combustion. Heated in the air it burns with a pale bluish flame. It is strongly poisonous, uniting with the hemoglobin of the blood.

CARBON DIOXIDE, CO_2 (Carbonic anhydride). *Prepared.* I.) By heating calcium carbonate. 2.) By treating carbonates with acids. 3.) By the complete combustion of carbon.

Properties. It is a colorless gas, generally with a faint acid odor, soluble in water, a non-supporter of combustion, and incombustible. It will not support life, but is non-poisonous. CARBONIC ACID, H_2CO_3, may be regarded as the compound of carbon dioxide and water. For tests, see Index.

CYANOGEN, $(CN)_2$. The radical (CN) is found in many compounds, among them, the following:

HYDROCYANIC ACID, HCN. A highly poisonous, volatile, colorless liquid, with odor of bitter almonds. The U. S. P. acid is a 2 per cent. solution. The acid and its salts, the Cyanides, are used in medicine and in the arts. Potassium Cyanide is official. For tests, see Index.

CYANIC ACID, HO(CN), from which we obtain the Cyanates; and ISO-CYANIC ACID, H(CN)O, and the Iso-Cyanates POTASSIUM SULPHOCYANATE or THIOCYANATE, KCNS; POTASSIUM FERRO-

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CYANIDE, $K_4Fe(CN)_6$, (Official), and POTASSIUM FERRICYANIDE, $K_3Fe(CN)_6$, are all used as test reagents.

CARBON DISULPHIDE, CS_2. Official. Colorless, highly refractive liquid with characteristic odor, used as a solvent.

SILICON.

Symbol, Si. Atomic weight, 28.2. Valence, IV.

The element is obtained in both crystalline and amorphous forms, but does not occur in the free state in nature.

SILICON DIOXIDE, SiO_2 (Silica). Occurs in nature as rock crystal, agate, quartz sand, etc. It is a hard, infusible substance, not attacked by ordinary acids, but dissolves in hydrofluoric acid, and is decomposed by fusion with alkali carbonates. The Silicates are salts of the silicic acids, H_4SiO_4, H_2SiO_3, etc.; thus Na_2SiO_3 is sodium silicate, a thick aqueous solution of which is called water-glass or soluble glass. It is used on bandages for making casts.

BORON.

Symbol, B. Atomic weight, 10.9. Valence, III.

Rare as an element. BORIC ACID, H_3BO_3, is a crystalline, odorless, slightly unctuous substance, soluble in 18 parts of water, in 15.3 parts of alcohol, and in 4.6 parts of glycerin, at 25° C. Soluble in 3 parts of boiling water. For tests, see Index.

TETRA-, or PYRO-BORIC ACID, $H_2B_4O_7$, has an important sodium salt, the SODIUM BORATE, $Na_2B_4O_7.10H_2O$, of the U. S. P. This occurs in colorless prisms or as a white powder, odorless, with sweetish alkaline taste. It is slightly efflorescent in dry air, soluble in 20 parts of water at 25° C., in 0.5 part of boiling water, insoluble in alcohol. Soluble in 1 part of glycerin at 80° C. For tests, see Index.

Other compounds are BORIC ANHYDRIDE, B_2O_3, and METABORIC ACID, HBO_2.

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THE METALS.

CLASSIFICATION FOR PURPOSES OF ANALYSIS.

The metals may be divided into six groups, according to their behavior with certain general, or *group reagents;* as follows:

GROUP I.—Metals forming *chlorides* insoluble in water, and consequently precipitated from solutions of their salts by Hydrochloric Acid. *Lead*, *Silver*, *Mercury* (*Mercurous*).

GROUP II.—Metals forming *sulphides* insoluble in water and in dilute acids, precipitated from acid solutions of their salts by Hydrogen Sulphide, after removal of first group metals.

(*a*) Sulphides soluble in warm yellow Ammonium Sulphide. *Arsenic*, *Antimony*, *Tin*, *Gold*, *Platinum*.

(*b*) Sulphides insoluble in warm yellow Ammonium Sulphide. *Mercury* (*Mercuric*), *Bismuth*, *Copper*, *Cadmium*.

GROUP III.—Metals precipitated by ammonium hydroxide in the presence of ammonium chloride after the removal of metals of first and second groups. *Iron*, *Aluminum*, *Chromium*.

GROUP IV.—Metals precipitated by hydrogen sulphide in alkaline solutions after removal of metals of preceding groups. *Cobalt*, *Nickel*, *Manganese*, *Zinc*.

GROUP V.—Metals precipitated with ammonium carbonate and sodium phosphate, after removal of metals of preceding groups. *Barium*, *Calcium*, *Strontium*, *Magnesium*.

GROUP VI.—Metals not precipitated by the preceding group reagents. *Lithium*, *Sodium*, *Potassium*, and the basic radical *Ammonium* (NH_4).

Qualitative Analysis is that subdivision of chemistry which treats of the methods used to identify elements or compounds.

In the analysis of salts, the metals or bases are first identified and then the acids with which they are combined.

One of the most important practical points to be remembered in qualitative analysis is that when an insoluble compound is pos-

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sible by double decomposition, as a rule it will be formed and precipitated.

In order to assist the student in knowing when a chemical action will take place and when an insoluble compound is possible the following *chemical principles* are given for careful consideration:

(1.) Acids when brought in contact with bases form corresponding salts.

(2.) All acetates, nitrates and chlorates are soluble, but salts of tin, bismuth and antimony require an excess of acid to keep them in solution.

(3.) All oxides and hydroxides are insoluble except those of sodium, potassium and ammonium. Sodium or potassium hydroxide will precipitate solutions of the salts of the metals of the first four groups and barium, strontium and calcium incompletely. The precipitate in most cases is a hydroxide, but with silver, mercury and antimony it is an oxide. The precipitate will redissolve with lead, antimony, tin, aluminium, chromium and zinc salts.

(4.) Ammonium hydroxide will precipitate solutions of the salts of the first four groups. The precipitate in most cases is a hydroxide, but with silver and antimony salts it is an oxide. With silver, copper, cadmium, cobalt, nickel and zinc salts the precipitate will redissolve.

(5) The chlorides of the metals of the first group are insoluble; lead chloride slightly soluble. Hydrochloric acid or soluble chlorides will precipitate solutions of metals of the first group.

(6.) The bromides of the metals of the first group are insoluble. Hydrobromic acid or soluble bromides will precipitate solutions of metals of the first group.

(7.) The iodides of lead, silver, mercury and cuprosum are insoluble. Hydriodic acid and soluble iodides precipitate solutions of the salts of lead, silver, mercury and copper. Cupric salts are precipitated as cuprous iodide with liberation of iodine. Arsenic and ferric salts are reduced with the liberation of iodine.

(8.) The sulphates of barium and strontium are insoluble; those of lead and calcium slightly soluble. Sulphuric acid or soluble sulphates will precipitate solutions of the salts of these metals; lead and calcium incompletely.

(9.) The sulphides of the first four groups are insoluble.

(a) Hydrogen sulphide precipitates from dilute acid solutions the metals of the first two groups.

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(b) Hydrogen sulphide in alkaline solution, or the soluble sulphides precipitate metals of the first four groups.

(10.) The carbonates of the sixth group metals are soluble and they precipitate solutions of other metals.

(a) The precipitate with antimony is an oxide.

(b) The precipitate with iron, aluminium and chromium is a hydroxide.

(c) The precipitate in most other cases is a normal carbonate.

Equations to Illustrate Chemical Principles.

The student is expected to write the symbols for the products formed, cite the principle governing the reaction, underline insoluble compounds formed and balance the equation.

1. $NaOH + HCl =$
2. $CaO + HNO_3 =$
3. $FeCl_3 + NH_4OH =$
4. $HgCl_2 + KOH =$
5. $NaCl + AgNO_3 =$
6. $HgNO_3 + CaCl_2 =$
7. $BaCl_2 + Ag_2SO_4 =$
8. $Hg(NO_3)_2 + KI =$
9. $Pb(NO_3)_2 + NaBr$
10. $CuSO_4 + H_2S =$
11. $Na_2CO_3 + SbCl_3 =$
12. $AgNO_3 + Na_2S =$
13. $Fe(NO_3)_3 + NaI =$
14. $H_2SO_4 + SrCl_2 =$
15. $CaI_2 + CuSO_4 =$
16. $FeSO_4 + Na_2CO_3 =$
17. $Cr_2(SO_4)_3 + NaOH =$
18. $ZnCl_2 + (NH_4)_2S =$
19. $Fe_2O_3 + H_2SO_4 =$
20. $FeCl_3 + HgNO_3 =$

Group I.

Lead, Silver, Mercury (Mercurous).

Lead.

Symbol, Pb. Atomic weight, 205.35. Valence, II.

A soft, bluish-white metal; tarnishes rapidly on exposure to air; malleable, melts at 325° C.; sp. gr. 11.37.

U. S. P. compounds: Acetate, Subacetate, Iodide, Nitrate, and Oxide.

Lead Acetate, $Pb(C_2H_3O_2)_2.3H_2O$. (Sugar of Lead.) A crystalline salt with slight acetous odor and sweetish, astringent, afterwards metallic, taste. Efflorescent and absorbing carbon dioxide on exposure to air. Soluble in 2 parts water, and in 30 parts alcohol. Lead Subacetate, U. S. P. A 25 per cent. solution of the basic salt $Pb(C_2H_3O_2)_2PbO$.

Lead Oxide, PbO. (Protoxide, Litharge.) A heavy, yellow-

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ish or reddish-yellow powder, odorless and tasteless. Absorbs, slowly, water and carbon dioxide from the air. Almost insoluble in water, insoluble in alcohol. A strong alkaline base.

LEAD DIOXIDE, PbO_2. A purple-brown powder, an oxidizing agent.

RED LEAD or MINIUM, Pb_3O_4. A red insoluble powder used in cements, as a pigment, in making of glass, etc.

LEAD CARBONATE, $PbCO_3$. The carbonate of commerce is the basic salt $2PbCO_3.Pb(OH)_2$ (White Lead). A heavy, white, insoluble powder.

Analytical Reactions. Use solutions of $Pb(NO_3)_2$.

1.—HCl and soluble chlorides precipitate white crystalline lead chloride, $PbCl_2$, soluble in hot water.

2.—H_2SO_4 precipitates white lead sulphate, $PbSO_4$, slightly soluble in water, freely soluble in ammoniacal solution of ammonium acetate.

3.—K_2CrO_4 precipitates yellow lead chromate, $PbCrO_4$, soluble in fixed alkalies.

4.—NH_4OH precipitates white basic lead hydroxide.

5.—H_2S precipitates black lead sulphide, PbS, insoluble in alkalies or alkaline sulphides but soluble in hot nitric acid.

6.—KI precipitates yellow lead iodide, PbI_2, soluble in hot water.

SILVER.

Symbol, Ag. Atomic weight, 107.12. Valence, I.

A white metal, ductile and malleable, the best conductor of heat and electricity. Does not oxidize on exposure to air, but tarnishes under the action of hydrogen sulphide. The salts of silver are decomposed by the action of light.

Official compounds: Cyanide, Nitrate, Oxide.

SILVER OXIDE, Ag_2O. Heavy brownish-black powder; with slight metallic taste, very slightly soluble in water, insoluble in alcohol.

SILVER CYANIDE, AgCN. A white powder, insoluble in water or in alcohol, soluble in potassium cyanide solution, and in ammonia water.

SILVER NITRATE, $AgNO_3$. Colorless, plate-like crystals, with bitter, caustic, metallic taste, soluble in 0.54 part water, in 24 parts alcohol. The Moulded Silver Nitrate, U. S. P. (Lunar

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Caustic) is made by mixing 100 parts silver nitrate with 4 parts hydrochloric acid and melting at lowest possible temperature, then pouring into moulds. The Mitigated Silver Nitrate is made by fusing silver nitrate with twice its weight of potassium nitrate.

Analytical Reactions. Use solution of $AgNO_3$.

1.—HCl and soluble chlorides precipitate white silver chloride, AgCl, soluble in NH_4OH, insoluble in HNO_3.

2.—KCN precipitates white AgCN, readily soluble in excess.

3.—H_2SO_4 produces no precipitate.

4.—K_2CrO_4 precipitates from neutral solutions, reddish-brown silver chromate, Ag_2CrO_4.

5.—H_2S precipitates black silver sulphide, Ag_2S.

MERCURY.

Symbol, Hg. Atomic weight, 198.5. Valence, I and II.

Occurrence in nature as the sulphide, HgS, cinnabar. A silver-white metal, liquid at ordinary temperatures; sp. gr. 13.535 at 25° C. Insoluble in ordinary solvents, in concentrated sulphuric acid, or, at ordinary temperatures, in hydrochloric acid. Soluble in nitric acid and in boiling hydrochloric acid. Forms amalgams with most metals. Used in medicine in trituration with honey and chalk (Hydrargyrum cum creta), in Mass of Mercury (Massa Hydrargyri), a trituration of mercury with honey of rose, glycerin, glycyrrhiza, and althæa, and in ointments.

U. S. P. compounds: *Mercurous* Chloride, Iodide; *Mercuric* Chloride, Iodide, Nitrate, Oxide, and Ammoniated Mercury.

MERCUROUS CHLORIDE, HgCl. (Mild Mercurous Chloride, Calomel.) Made by subliming a mixture of the sulphate of mercury, with mercury, and sodium chloride. A heavy, white, impalpable powder, odorless and tasteless, permanent in air, insoluble in water, in alcohol, or in cold dilute acids. Turns black on addition of ammonia water.

MERCUROUS IODIDE, HgI. (Yellow, Green, or Protiodide.)

MERCUROUS OXIDE, Hg_2O. (Black Oxide.) Present in "Black wash."

MERCURIC CHLORIDE, $HgCl_2$. (Corrosive Sublimate, Bichloride of Mercury.) Made by subliming a mixture of mercuric sulphate with sodium chloride. A heavy, white, odorless, crystalline substance with persistent metallic taste, permanent in air, soluble in 13 parts water, and in 3 parts alcohol. AMMONIATED MERCURY,

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NH_2HgCl. (White Precipitate.) Made by adding ammonia water to a solution of mercuric chloride.

MERCURIC IODIDE, HgI_2. A scarlet amorphous powder, odorless and tasteless, almost insoluble in water, soluble in 116 parts alcohol.

MERCURIC OXIDE, HgO. In two forms, yellow and red, the former being in a state of finer subdivision. Heavy, amorphous, odorless powder with a slight metallic taste, permanent in air, almost insoluble in water, insoluble in alcohol, soluble in dilute hydrochloric acid and in nitric acid. The "Yellow Wash" of pharmacy, made by adding mercuric chloride to lime water, contains mercuric oxide in suspension. The Oleate of Mercury, a constituent of Mercurial Plaster and of Mercurial Ointment, is a trituration of the yellow oxide with oleic acid. The red oxide is used in form of an ointment.

It must be kept in mind that mercury forms two series of compounds, mercurous and mercuric, the former being combinations where mercury has a valence of one, the latter with two.

As the mercuric compounds are usually much more toxic the following differences in analytic reactions must be remembered:

Analytical reactions for mercurous compounds. Use solution of $Hg(NO_3)$.

1.—HCl precipitates white mercurous chloride, HgCl, which turns black on addition of NH_4OH, mercurous ammonium chloride, NH_2Hg_2Cl being formed.

2.—K_2CrO_4 precipitates orange mercurous chromate, Hg_2CrO_4.

3.—KI precipitates yellowish-green mercurous iodide, HgI.

4.—H_2S precipitates black mercuric sulphide, HgS, mixed with mercury.

Analytical reactions for mercuric compounds. Use solution of $HgCl_2$.

1.—H_2S gas precipitates black mercuric sulphide, HgS, insoluble in HNO_3, HCl or in alkaline sulphides.

2.—NaOH precipitates yellow mercuric oxide, HgO.

3.—NH_4OH precipitates white mercur-ammonium chloride, "Ammoniated Mercury," NH_2HgCl.

4.—$SnCl_2$ precipitates white mercurous chloride, HgCl.

$$2HgCl_2 + SnCl_2 = 2HgCl + SnCl_4.$$

An excess of the reagent precipitates gray metallic mercury.

$$HgCl_2 + SnCl_2 = Hg + SnCl_4.$$

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5.—KI precipitates yellow to scarlet mercuric iodide, HgI_2, soluble in excess.

	Solutions of Mercurous Salts.	*Solutions of Mercuric Salts.*
Hydrochloric Acid	White ppt.	No ppt.
Ammonium Hydroxide	Black ppt.	White ppt.
Potassium Iodide	Yellow or green ppt.	Red ppt.
Potassium, Calcium or Sodium Hydroxide	Black ppt.	Yellow ppt.

Mercurous salts belong to first group and mercuric to second group, because only mercurous salts are precipitated from their solutions by hydrochloric acid.

Separation and Analysis of Group I. Metals.

To solution to be tested add dilute hydrochloric acid drop by drop as long as a precipitate is formed. This will precipitate the metals of Group I. (Principle 5). Filter, and wash the precipitate with cold water. This filtrate and first washings may contain the salts of metals of 2d, 3rd, 4th, 5th and 6th Groups, and must be saved and treated as directed under Group II.

Pour boiling water on the filter containing the 1st group precipitate. If lead chloride is present it will partly dissolve in hot water. The filtrate is divided into four portions, and each portion tested for *lead* as follows:

1. Add a few drops of dilute sulphuric acid.=A white precipitate.
2. Add a few drops of potassium iodide.=A yellow precipitate.
3. Add a few drops of potassium chromate.=A yellow precipitate.
4. Add a few drops of hydrogen sulphide solution.=A black precipitate.

Add ammonium hydroxide to filter and collect filtrate. Silver chloride will be dissolved by the ammonium hydrate. If solution is not clear, clarify by returning to filter. Add HNO_3 till solution is acid in reaction and a white precipitate indicates *silver*.

If ammonium hydroxide turns the residue black, it may be inferred that *mercurous compounds* are present.

Group II.

Arsenic, Antimony, Tin, Gold, Platinum, Mercury (Mercuric), Bismuth, Copper, Cadmium.

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ARSENIC.

Symbol, As. Atomic weight, 74.4. Valence, III, V.

U. S. P. Compounds.—Iodide, Trioxide, Sodium Arsenate, Potassium Arsenite.

HYDROGEN ARSENIDE, ARSINE, AsH_3. A very poisonous gas generated by action of nascent* hydrogen on a reducible arsenical compound.

ARSENIC TRIOXIDE, As_2O_3. (Arsenous Acid, Oxide, or Anhydride.) White Arsenic. A heavy white powder, or transparent vitreous, or opaque, porcelain-like masses, odorless and tasteless. The vitreous variety dissolves slowly, in about 30 parts water at 25°, the porcelain-like variety, and the powder, in about 100 parts water. Sparingly soluble in alcohol, soluble in hydrochloric acid and in alkalies. The U. S. P. solution contains one per cent. of the oxide with 5 per cent. dilute hydrochloric acid.

POTASSIUM ARSENITE, K_2HAsO_3. The U. S. P. solution (Fowler's solution) is made by boiling 1 part of the oxide with two parts of potassium bicarbonate in 94 parts water, finally adding 3 parts compound tincture of lavender. This solution contains the arsenite and also the metarsenite, $KAsO_2$.

COPPER ARSENITE, $CuHAsO_3$. (Scheele's Green.)

COPPER ACETO-METARSENITE, $Cu(C_2H_3O_2)_2.3Cu(AsO_2)_2$. (Paris or Schweinfurth Green.)

ARSENOUS IODIDE, AsI_3. Orange-red, odorless, crystalline powder, soluble with partial decomposition in about 12 parts water, and in 28 parts alcohol.

ARSENIC DISULPHIDE, As_2S_2. (Realgar.) ARSENIC TRISULPHIDE, As_2S_3. (Orpiment.)

Analytical reactions. Use aqueous solution of As_2O_3.

1.—Acidify with HCl, and pass H_2S gas through the solution. A precipitate of yellow As_2S_3 is formed, insoluble in hot HCl, soluble in alkalies and in alkaline sulphides and carbonates.

2.—Silver-ammonium nitrate precipitates yellow silver arsenite, Ag_3AsO_3, soluble in excess of ammonium hydroxide.

3.—Cupric ammonium sulphate precipitates green copper arsenite, $CuHAsO_3$, soluble in excess of ammonium hydroxide.

4.—*Marsh's Test.*—The apparatus consists of a flask provided

* An element is said to be in a nascent condition immediately after it has been set free from its compounds. Nascent elements are especially active chemically.

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with a safety tube, for the introduction of the solution, and a delivery tube for the exit of the gases evolved. The latter pass into a wide tube containing calcium chloride, and thence into a long tube of smaller bore, contracted at intervals and drawn to a fine point at the end. Zinc, water, and sulphuric acid are brought together in the flask, and the solution under analysis added. Hydrogen gas, and, in presence of arsenical compounds, hydrogen arsenide gas are produced. The inflammable gas issuing at the end of the tube, in presence of hydrogen arsenide, burns with a bluish-white flame, and gives off white fumes which may be collected and examined microscopically for crystals of As_2O_3. If a cold surface, such as a piece of porcelain, be held in the flame, metallic arsenic is deposited in a brilliant steel-gray to brown mirror. By heating the long tube near one of its contractions a fine mirror of arsenic is deposited on the glass just in advance of the flame. If the gas be passed into a solution of silver nitrate, metallic silver is deposited in black flakes. After filtering and removing excess of silver nitrate, the clear solution may be tested for arsenic. Antimony gives somewhat similar tests, but may easily be distinguished. (See under Antimony.) Organic matter must be absent and the reagents used must be known to be free from arsenic. Extreme care must be taken in lighting the hydrogen and in not breathing the arsine.

5.—*Fleitmann's Test.*—This is similar to Marsh's Test, depending upon the production of hydrogen arsenide by the action of nascent hydrogen on a reducible arsenical compound. Potassium hydroxide or sodium hydroxide is placed with zinc in a test-tube and the solution to be tested added. A paper moistened with silver nitrate is held at the mouth of the tube; the mixture is boiled, and in the presence of arsenic the paper is blackened by the reduction of the silver nitrate to metallic silver. This test is not given by antimony.

6.—*Reinsch's Test.*—The solution to be tested is acidulated with hydrochloric acid, a strip of pure bright copper foil is introduced and the mixture boiled. In the presence of arsenical compounds, a steel-gray deposit of arsenic forms upon the copper. Antimony, mercury, and even organic matter, may produce a similar appearance, but the arsenic may be identified as follows: The copper slip is removed, washed carefully, and dried between folds of filter paper. A strip is then cut, rolled into a small coil, introduced

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into a clean reduction-tube and heated. The arsenic volatilizes, and collects in the cooler portion of the tube in white octahedral crystals of As_2O_3. Organic matter is burned away without the formation of a sublimate. (For Antimony and Mercury, see below.)

7.—(Use solid As_2O_3.) Place a small particle of arsenous oxide in a reduction tube, and above it in the tube a splinter of charcoal. Heat first the coal, then the arsenic; a mirror of metallic arsenic will form on the glass above the coal. Remove the coal and heat the mirror; a crystalline sublimate of arsenous oxide will be obtained in the cool portion of the tube.

8.—*Gutzeit's Test.*—In a long test-tube place about 1 Gm. of arsenic-free zinc and 4 c.c. dilute sulphuric acid, along with a small amount of the solution to be tested.

Wet a piece of cheese cloth about 5 cm. square with a solution of lead acetate, and place in tube toward the upper end. Secure with rubber band over the top of tube, a double thickness of filter paper, and apply one drop of a saturated solution of silver nitrate slightly acidulated with nitric acid. Protect the tube from the light and examine after 30 minutes. If arsenic is present the gas Arsine (AsH_3) will be formed, which will produce a bright yellow spot on the filter paper, due to the formation of the double salt $Ag_3As(AgNO_3)_3$. If the spot be moistened with a drop of water its color turns brown or black on account of the metallic silver formed.

$$Ag_3As(AgNO_3)_3 + 3H_2O = 3Ag_2 + 3HNO_3 + H_3AsO_3.$$

Extreme care must be taken with this test. If the zinc contains sufficient sulphides to turn the lead acetate cloth all black or a trace of arsenic is present in the reagents, the test is of no value. Blank tests should always be made.

If antimony is present the color produced on the filter paper is brown or black without being preceded with the yellow.

ANTIMONY.

Symbol, Sb. Atomic weight, 119.3. Valence, III, V.

Official compound: Antimony and Potassium Tartrate.

ANTIMONY AND POTASSIUM TARTRATE, $2KSbOC_4H_4O_6.H_2O$. (Tartar emetic.) Prepared by boiling the oxide, Sb_2O_3, with potassium acid tartrate in water. Colorless, transparent, rhombic crystals, becoming opaque-white on exposure to air; or as a white

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granular powder. Odorless, with a sweetish, afterwards disagreeable metallic taste, soluble in 15.5 parts water, insoluble in alcohol. Wine of Antimony is a 0.4 per cent. solution of tartar emetic in water, alcohol, and white wine.

ANTIMONY CHLORIDE, $SbCl_3$. (Butter of Antimony.) A deliquescent, crystalline substance, soluble in a small amount of water, but decomposed by an excess with precipitation of the oxychloride, SbOCl (Powder of Algaroth).

Analytical reactions to be compared with those given under Arsenic. Use Tartar Emetic solution.

1.—NaOH and NH_4OH precipitate antimonous hydroxide, $Sb(OH)_3$. Soluble in excess of the reagent with NaOH, but not with NH_4OH.

2.—Acidify with HCl and pass H_2S gas: an orange precipitate of Sb_2S_3 is formed. Soluble in sodium hydroxide, in yellow ammonium sulphide, but insoluble in alkaline carbonates.

3.—In the absence of tartaric or citric acids, *e. g.*, in solutions of the chloride, $SbCl_3$, an excess of water produces a precipitate of a basic salt, the oxychloride, SbOCl.

4.—*Marsh's Test.*—This test is performed as described under arsenic, similar mirrors of metallic nature being formed. Antimony is distinguished from arsenic as follows: The deposit obtained by holding a cold surface in the flame is insoluble in solutions of sodium or calcium hypochlorite (arsenic spots—soluble). If the spot be dissolved in a drop of nitric acid, the solution evaporated to dryness, and the residue moistened with a drop of silver nitrate, no color is developed (arsenic—a brick-red color). The spot dissolved in ammonium sulphide and evaporated to dryness, yields an orange-red residue (arsenic—bright yellow). The antimony mirror obtained by heating the tubes is formed immediately above the flame (with arsenic, in advance of the flame), is darker than the arsenical mirror and less volatile. Hydrogen antimonide does not precipitate metallic silver from solutions of silver nitrate, but does precipitate black silver antimonide.

5. —*Reinsch's Test.*—Performed as indicated under arsenic. The antimony coating is distinguished from arsenic by the fact that when heated in the reduction-tube, the sublimate produced is either amorphous or composed of fine acicular crystals.

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TIN.

Symbol, Sn. Atomic weight, 118.1. Valence, II, IV.

Chief occurrence in nature as the oxide. A silver-white metal, permanent in air at ordinary temperatures.

No official compounds.

STANNOUS CHLORIDE, $SnCl_2.2H_2O$. Made by dissolving tin in hydrochloric acid, is a valuable reducing agent; dissolves in a small amount of water, but is precipitated by an excess as basic chloride.

STANNIC CHLORIDE, $SnCl_4$. A fuming liquid.

Analytical reactions for Stannous Compounds. Use $SnCl_2$ solution.

1.—H_2S precipitates brown SnS, soluble in yellow ammonium sulphide, in NaOH, and in boiling HCl.

2.—NH_4OH precipitates white H_2SnO_2, slightly soluble in excess.

3.—$HgCl_2$ precipitates Hg_2Cl_2. On boiling, metallic mercury separates out.

Analytical reactions for Stannic Compounds. Use $SnCl_4$ solution.

1.—H_2S precipitates yellowish SnS_2, soluble in yellow alkaline sulphides, in NaOH and in boiling HCl.

2.—NH_4OH precipitates white stannic acid, H_2SnO_3, insoluble in excess.

GOLD.

Symbol, Au. Atomic weight, 195.7. Valence, I, III.

A soft, yellow, ductile, malleable metal, not acted upon by ordinary reagents, attacked by chlorine, bromine, and by mercury. Soluble in nitrohydrochloric acid.

Official compound: Gold and sodium chloride.

GOLD CHLORIDE, $AuCl_3$. Made by dissolving the metal in nitrohydrochloric acid and evaporating the solution. An orange-yellow, very soluble powder. GOLD AND SODIUM CHLORIDE. A mixture of equal parts gold chloride aud sodium chloride, representing not less than 30 per cent. metallic gold. An orange-yellow, odorless powder, with saline metallic taste, deliquescent in damp air, very soluble in water, and at least one-half of it soluble in cold alcohol.

Analytical Reactions. Use $AuCl_3$ solution.

1.—H_2S precipitates black Au_2S_3 (from hot solutions Au_2S) insoluble in HCl or in $(NH_4)_2CO_3$, soluble in nitrohydrochloric acid and in yellow ammonium sulphide.

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2.—$H_2C_2O_4$ or $FeSO_4$, boiled with solutions of gold, precipitates the latter in the form of a dark brown powder.

3.—$SnCl_2$ or, better, a mixture of $SnCl_2$ with $FeCl_3$, precipitates mixed oxides of gold and tin, "Purple of Cassius."

4.—NH_4OH precipitates reddish ammonium aurate, "fulminating gold," $Au_2(NH_3)_2O_2$.

Platinum.

Symbol, Pt. Atomic weight, 193.3. Valence, IV.

A grayish-white, lustrous metal, ductile and malleable, may be welded at a red heat, melts at 1800° C. Not attacked by ordinary acids, soluble in nitrohydrochloric acid, and, at a red heat, is acted upon by caustic alkalies, by alkali cyanides, by sulphur, and by phosphorus. No official compounds.

Platinum Chloride, $PtCl_4.5H_2O$. By dissolving platinum in nitrohydrochloric acid and evaporating off the nitric acid, chloroplatinic acid, $PtCl_4.2HCl.6H_2O$, is obtained, and it is this substance dissolved in water (2.6 grammes in 20 c.c. water) which is ordinarily used under the name of platinum chloride. The crystals are brownish-yellow, deliquescent, and dissolve to a golden-yellow solution.

Analytical Reactions. Use $PtCl_4$ solution.

1.—H_2S precipitates brown PtS_2, insoluble in HCl or in $(NH_4)_2CO_3$. Soluble in yellow ammonium sulphide, and in nitrohydrochloric acid.

2.—KCl precipitates yellow crystalline K_2PtCl_6, best after addition of alcohol.

3.—NH_4Cl precipitates yellow crystalline $(NH_4)_2PtCl_6$, best after addition of alcohol.

Bismuth.

Symbol, Bi. Atomic weight, 206.9. Valence, III.

Official compounds: Bismuth and Ammonium Citrate, Citrate, Subcarbonate, Subgallate, Subnitrate, Subsalicylate.

Bismuth Subnitrate. Made by decomposing the nitrate $Bi(NO_3)_3$ with excess of water. Composition variable, generally represented as $BiONO_3H_2O$. A white, odorless, almost tasteless powder, permanent in air, almost insoluble in water, insoluble in alcohol, readily soluble in nitric acid and in hydrochloric acid.

Analytical Reactions. Use solution of $Bi(NO_3)_3$.

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1.—H_2S gas, precipitates black bismuth sulphide, Bi_2S_3. Soluble in boiling nitric acid, but insoluble in alkalies or in alkaline sulphides.

2.—NaOH and NH_4OH precipitate white bismuth hydroxide, $Bi(OH)_3$.

3.—H_2O, in excess, precipitates a basic salt of bismuth, bismuth subnitrate, $BiONO_3$.

COPPER.

Symbol, Cu. Atomic weight, 63.1. Valence, I, II.

A red, malleable, ductile metal, an excellent conductor of heat and electricity, permanent in dry air. In moist air becomes covered with a film of the subcarbonate, $CuCO_3Cu(OH)_2$. Soluble in hot sulphuric acid with evolution of sulphur dioxide; soluble in nitric acid with evolution of nitrogen dioxide. Only slightly acted upon by other acids.

Official compound: Sulphate.

CUPROUS OXIDE, Cu_2O. Red oxide of copper. CUPROUS HYDROXIDE, $Cu(OH)$, yellow.

CUPRIC OXIDE, CuO. Black oxide of copper.

CUPRIC HYDROXIDE, $Cu(OH)_2$. A bluish-white precipitate obtained from solution of a cupric salt by addition of an alkali.

CUPRIC SULPHATE, $CuSO_4.5H_2O$. (Blue Vitriol.) Large, transparent, blue, triclinic crystals; odorless, with nauseous metallic taste, slowly efflorescent in dry air, soluble in 2.2 parts water, and in 400 parts alcohol.

COPPER SUBACETATE, $Cu(C_2H_3O_2)_2CuO$.

COPPER ARSENITE and COPPER ACETO-METARSENITE, see under Arsenic.

Analytical Reactions. Use $CuSO_4$ solution.

1.—H_2S gas precipitates black cupric sulphide, CuS, soluble in hot nitric acid, practically insoluble in alkalies or in alkaline sulphides.

2.—NH_4OH precipitates bluish cupric hydroxide, $Cu(OH)_2$ soluble in excess, forming a dark blue solution.

3.—NaOH precipitates blue cupric hydroxide, $Cu(OH)_2$, insoluble in excess, turning black on boiling.

4.—$K_4Fe(CN)_6$ precipitates from neutral or acid solutions, reddish-brown cupric ferrocyanide, $Cu_2Fe(CN)_6$.

5.—Copper compounds impart a green color to the Bunsen flame.

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CADMIUM.

Symbol, Cd. Atomic weight, 111.6. Valence, II.

Resembles zinc in many respects. No official compounds.

CADMIUM SULPHIDE, CdS. A yellow pigment. CADMIUM SULPHATE, $CdSO_4$, CADMIUM IODIDE, CdI_2, and CADMIUM BROMIDE, $CdBr_2$, are used occasionally in medicine.

Analytical Reactions. Use $CdCl_2$ solution.

1.—H_2S precipitates yellow CdS, insoluble in alkaline sulphides, insoluble in KCN, soluble in hot dilute H_2SO_4.

2.—NaOH precipitates white $Cd(OH)_2$, insoluble in excess.

3.—NH_4OH precipitates white $Cd(OH)_2$, insoluble in excess.

4.—$(NH_4)_2S$ precipitates yellow CdS.

SEPARATION AND ANALYSIS OF GROUP II. METALS.

Warm filtrate from Group I. and add hydrogen sulphide as long as a precipitate is formed. Filter and thoroughly wash the precipitate with hot water. Save filtrate and first washings for examination for 3rd, 4th, 5th and 6th group metals.

Transfer the filter paper and precipitate to an evaporating dish half full of yellow ammonium sulphide. Heat *gently* about five minutes, stirring with glass rod till filter paper is completely disintegrated. Filter.

The sulphides of portion A, namely, arsenic, antimony and tin, are dissolved and will be in the filtrate. The other sulphides are not soluble and will remain on filter paper.

Portion A. Filtrate containing Arsenic, Antimony and Tin.

Acidify the filtrate with dilute HCl. The sulphides, if present, are reprecipitated.* Filter, and wash the precipitate. Perforate the filter paper and wash the precipitate into a large test-tube. Add some fragments of solid $KClO_3$ and boil for several minutes. Add water, filter and wash.

The Marsh Test, see page 34, may now be applied to the clear solution.

Fill flask about one-fourth full of water and add several pieces of arsenic-free zinc. Add sulphuric acid through the thistle tube until a rapid evolution of hydrogen takes place. Fill the test tube two-thirds full of dilute silver nitrate solution and conduct the gas into

*A fine, yellowish-white precipitate here may result from decomposition of the ammonium sulphide by the acid.

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it. No dark color should be formed in the solution of silver nitrate, after apparatus has been started. Add solution suspected to contain arsenic, antimony and tin. Either arsenic or antimony will cause a dark precipitate to form in the dilute solution of silver nitrate; the tin will be deposited on the zinc and may be tested for by dissolving the zinc later in hydrochloric acid, filtering and adding mercuric chloride which will produce a white or brown precipitate if *tin* be present.

If arsenic is present it will be found in solution in the test tube. If antimony is present it will be found along with the black precipitate.

Filter and wash black precipitate with hot water, discard washing but save filtrate as it may contain arsenic.

Dissolve black precipitate with hydrochloric acid using heat if necessary; add water, filter and to the filtrate add hydrogen sulphide; an orange precipitate will be formed if *antimony* is present.

The filtrate, which may contain arsenic, will probably contain some excess of silver nitrate which must be removed by adding a sufficient quantity of hydrochloric acid to precipitate all of the silver. Filter, and to this filtrate add hydrogen sulphide—a yellow color or precipitate indicates *arsenic.* Care must be taken to flush the entire apparatus with water just as soon as the tube of silver nitrate is removed. Arsenic fumes are very dangerous, and it is wise to hold the breath while washing out the apparatus. The zinc may now be removed and tested for tin as directed above, or tin may be tested for separately from the original solution, as follows:

Add an excess of potassium hydroxide to original solution to be tested, filter. Add the filtrate to an ammoniacal solution of silver nitrate, a black precipitate will be formed if *tin* be present.

Portion B. Residue containing Gold, Platinum, Mercury, Bismuth, Copper, Cadmium and Lead.

Transfer residue and filter-paper to an evaporating dish half filled with a mixture of equal parts of water and nitric acid; boil for several minutes, stirring with glass rod. All of the sulphides of portion B will dissolve except mercuric sulphide. Filter and wash. The mercuric sulphide may be identified by dissolving in a hot mixture of equal parts nitric and hydrochloric acids, boiling away the excess of the acids, adding water, and then filtering. To this filtrate add stannous chloride. A white or brown precipitate indicates *mercuric salts.*

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Evaporate the filtrate containing the other metals almost to dryness, add water, then a drop of sulphuric acid. A white precipitate will be formed if *lead* is present. Filter if necessary.

Add ammonium hydroxide till STRONGLY alkaline. A white precipitate indicates *bismuth*. If a precipitate is formed, filter and to the precipitate on the filter paper add a FRESH solution of potassium stannite,* which will turn the precipitate a dark color if bismuth is present.

Divide the filtrate after removal of bismuth in three portions.

Acidify first portion with acetic acid, then add potassium ferrocyanide—a brown color indicates *copper*.

Add hydrogen sulphide to second portion. If a yellow precipitate is formed, *cadmium* is indicated.

If a dark color is obtained with second portion add to third portion an equal volume of solution of potassium cyanide and then VERY SLOWLY hydrogen sulphide.

GROUP III.

Iron, Aluminum, Chromium.

IRON.

Symbol, Fe. Atomic weight, 55.5. Valence, II, III.

Chief occurrence in nature as oxides, Fe_2O_3 and Fe_3O_4. The metal is prepared by reduction of the oxides by means of carbon.

Reduced Iron, made by the action of hydrogen on pure ferric oxide, is a fine, grayish-black, lusterless, magnetic powder.

Official compounds: *Ferrous*—Carbonate, Iodide, Sulphate, Ferrocyanide of Potash; *Ferric*—Chloride, Citrate, Hydroxide, Hypophosphite, Phosphate, Pyrophosphate, Subsulphate, Sulphate, and Ferric Ammonium Sulphate.

FERROUS CARBONATE, $FeCO_3$. Occurs in nature, and may be made by mixing solutions of ferrous sulphate and sodium bicarbonate.

FERROUS SULPHATE, $FeSO_4.7H_2O$. (Copperas, Green Vitriol.) Pale bluish-green crystals, of saline, styptic taste, efflorescent in dry air, and oxidizing in moist air, soluble in water, insoluble in alcohol.

* Potassium stannite is made by taking about one-fourth test-tubeful of solution of $SnCl_2$ and adding a solution of KOH until the precipitate is nearly but not completely redissolved. Filter.

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FERROUS SULPHIDE, FeS. Made by fusing together sulphur and iron filings. Used as a reagent for generating hydrosulphuric acid.

FERRIC OXIDE, Fe_2O_3. Chief ore of iron. Made artificially by heating ferrous sulphate. A reddish-brown powder used for polishing, etc.

FERRIC HYDROXIDE, $Fe(OH)_3$. Reddish-brown precipitate, obtained on adding ammonia water to a solution of a ferric salt.

FERRIC CHLORIDE, $FeCl_3$. Made by dissolving ferric oxide in hydrochloric acid, or (U. S. P. method) by dissolving iron in hydrochloric acid, and then oxidizing the ferrous chloride obtained by means of nitric acid. The nitric acid is then removed by heating. Orange-yellow crystalline masses with styptic taste, deliquescent, soluble in water and in alcohol. The Tincture of Ferric Chloride, U. S. P., is made by mixing the solution, prepared as above, with alcohol, and letting it stand for at least three months.

Analytical Reactions for Ferrous Compounds. Use fresh $FeSO_4$ solution.

1.—NaOH, or NH_4OH, precipitates white or greenish-white $Fe(OH)_2$, turning brown on exposure to air.

2.—$(NH_4)_2S$ precipitates black ferrous sulphide, FeS.

3.—$K_4Fe(CN)_6$ precipitates bluish-white potassium ferrous ferrocyanide $K_2Fe_2(CN)_6$.

4.—$K_3Fe(CN)_6$ precipitates dark blue ferrous ferrocyanide, $Fe_3[Fe(CN)_6]_2$, known as Turnbull's blue.

5.—KCNS gives no reaction.

Analytical Reactions for Ferric Compounds. Use $FeCl_3$ solution.

1.—NaOH, or NH_4OH, precipitates reddish-brown ferric hydrate, $Fe(OH)_3$.

2.—$(NH_4)_2S$ precipitates black ferrous sulphide, FeS.

3.—$K_4Fe(CN)_6$ precipitates ferric ferrocyanide, $Fe_4[Fe(CN)_6]_3$, known as Prussian blue.

4.—KCNS produces a blood-red color, due to formation of ferric sulphocyanate, $Fe(CNS)_3$. The color is destroyed by addition of $HgCl_2$.

5.—$K_3Fe(CN)_6$ produces no precipitate but imparts a green or brown color to the solution.

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ALUMINUM.

Symbol, Al. Atomic weight, 26.9. Valence, III.

Chief occurrence in nature as the silicate. The metal is prepared by electrolysis of the double fluoride of aluminum and sodium with aluminum hydroxide, in the presence of carbon. A silvery-white metal, sp. gr. 2.67, hard, ductile and malleable, is tarnished only superficially by air, resists the action of nitric and sulphuric acids, but dissolves in hydrochloric acid, and in solutions of the alkalies.

Official compounds: Hydroxide, Sulphate, Potassium and Aluminum Sulphate (Alum).

ALUMINUM HYDROXIDE, $Al(OH)_3$. A light, white, amorphous, odorless, tasteless powder, permanent in air, insoluble in water or alcohol.

ALUMINUM SULPHATE, $Al_2(SO_4)_3.16H_2O$. A white crystalline powder with sweetish astringent taste, permanent in air, soluble in water, insoluble in alcohol.

ALUM [U. S. P.—$AlK(SO_4)_2.12H_2O$]. Made on the commercial scale by decomposing clay, the silicate of aluminum, with sulphuric acid, adding to the solution potassium sulphate, and then evaporating. Large, colorless, odorless crystals, with sweetish, astringent taste, soluble in 9 parts water, insoluble in alcohol. Heated to 200° C. the water of crystallization is driven off and "burnt alum" (Alumen exsiccatum, U. S. P.) is formed. This is a white powder which attracts moisture from the air.

Analytical Reactions. Use $AlCl_3$ solution.

1.—NH_4OH precipitates white aluminum hydroxide, $Al(OH)_3$, insoluble in moderate excess.

2.—NaOH precipitates white aluminum hydroxide, $Al(OH)_3$. Soluble in excess of reagent, but reprecipitated by boiling with excess of NH_4Cl.

3.—Both $(NH_4)_2S$ and $(NH_4)_2CO_3$ precipitate white aluminum hydroxide.

$$Al_2Cl_6 + 3(NH_2)_2S + 6H_2O = 2Al(OH)_3 + 6NH_4Cl + 3H_2S.$$

4.—Na_2HPO_4, in presence of sodium acetate, precipitates aluminum phosphate, $AlPO_4$. The precipitate is soluble in sodium or potassium hydroxide, in HCl, or in HNO_3; it is insoluble in NH_4OH, NH_4Cl, or $HC_2H_3O_2$.

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Chromium.

Symbol, Cr. Atomic weight, 51.7. Valence, III, VI.

Official compounds: Trioxide and Potassium Dichromate.

Chromium Trioxide, CrO_3. (Chromic Acid, Chromic Anhydride.) Made by adding sulphuric acid to a strong solution of potassium dichromate. Small, odorless, needle-like, purplish-red crystals. The commercial preparation is deliquescent, very soluble in water, a strong oxidizing agent, decomposes organic solvents, alcohol, etc., with dangerous violence.

Chromic Oxide, Cr_2O_3. A green powder, insoluble in water, acids, or alkalies, used as a pigment in glass and porcelain.

Chromic Sulphate, $Cr_2(SO_4)_3.12H_2O$. A violet-colored salt giving a violet solution which turns green when heated. The double salt with ammonium, $Cr_2(SO_4)_3(NH_4)_2SO_4.24H_2O$ is known as Chrome Alum.

Potassium Chromate, K_2CrO_4, yellow, and Potassium Dichromate, $K_2Cr_2O_7$, orange-red, are both, especially the latter, valuable laboratory reagents.

Analytical Reactions. Use solution of $CrCl_3$.

1.—NH_4OH precipitates light green chromium hydroxide, $Cr(OH)_3$.

2.—NaOH precipitates light green chromium hydroxide, $Cr(OH)_3$. Soluble in excess, but precipitated on boiling.

3.—$(NH_4)_2S$ precipitates light green chromium hydroxide, $Cr(OH)_3$.

Separation and Analysis of Group III. Metals.

The method to be used for Group III. will be determined by the presence or absence of phosphoric acid. Organic acids, *e. g.*, oxalic acid, tartaric acid, citric acid, etc., should be absent in any case, and, if present, should be destroyed by evaporation of the solution to dryness and ignition of the residue. The ignited residue is then dissolved in water and hydrochloric acid, and the analysis proceeded with.

To test for phosphoric acid, dissolve a portion of the precipitate obtained on addition of NH_4Cl and NH_4OH (see scheme below) in dilute HNO_3, and add two volumes of ammonium molybdate solution. A yellow precipitate indicates presence of phosphoric acid.

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GROUP III. (PHOSPHATES ABSENT.)

Boil the filtrate from Group II *until all* H_2S *is expelled*, add a *few drops* of strong HNO_3 and again heat to boiling. Add NH_4Cl and NH_4OH, and, if there be a precipitate, filter at once. Reserve the filtrate for Group IV.

Precipitate: $Al(OH)_3$, white gelatinous; $Cr(OH)_3$, green; $Fe(OH)_3$, reddish brown. Transfer precipitate to an evaporating dish and add potassium hydroxide. Boil a few minutes and filter.

Residue $Cr(OH)_3$ and $Fe(OH)_3$. Fuse on platinum foil with KNO_3 and Na_2CO_3, cool, digest in warm water and filter.		Solution $KAlO_2$. Make solution *slightly* acid with HCl then add $(NH_4)_2CO_3$. A white ppt. indicates aluminum.
Residue Fe_2O_3. Dissolve in HCl and test for iron with KCNS = red. $K_4Fe(CN)_6$ = blue.	Solution Na_2CrO_4 and K_2CrO_4. Acidify with $HC_2H_3O_2$ and add a solution of $Pb(C_2H_3O_2)_2$ = A yellow precipitate indicates chromium.	

GROUP III. (PHOSPHATES PRESENT.)

Boil the filtrate from Group II until all H_2S is expelled, add a few drops of strong HNO_3 and again heat to boiling. Add NH_4Cl and NH_4OH, and filter. To the filtrate add $(NH_4)_2S$ and filter. (Reserve the filtrate for Group V.) Wash the two precipitates and then digest them together in a dish with $(NH_4)_2S$. Filter and wash. Dissolve the precipitate in hot dilute HCl, with addition of a small crystal of $KClO_3$. Drive off the chlorine by heat and filter off any separated sulphur. Nearly neutralize the solution by adding dilute sodium carbonate, and then add an acetic acid solution of sodium acetate. Warm, and filter immediately.

The Precipitate is boiled with NaOH for several minutes, and tested for **Fe, Cr, and Al**, as described in the last scheme, in absence of phosphates.	To *the Filtrate* add $FeCl_3$ drop by drop, as long as a precipitate forms. Warm for some time, and filter. To the filtrate add NH_4Cl and NH_4OH, and proceed with the analysis of Group IV.

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Group IV.

Nickel, Cobalt, Manganese, Zinc.

Nickel.

Symbol, Ni. Atomic weight, 58.3. Valence, II.

A lustrous white metal, ductile, malleable, and magnetic. Does not tarnish on exposure to air. The salts are mostly green or blue in solution, the anhydrous salts, yellowish-green.

No official compounds.

Analytical reactions. Use $NiSO_4$ solution.

1.—NaOH precipitates pale green $Ni(OH)_2$, insoluble in excess and unaltered by boiling.

2.—NH_4OH precipitates pale green $Ni(OH)_2$, soluble iu excess and in ammonium salts, to a violet-blue solution.

3.—$(NH_4)_2S$ precipitates black NiS, insoluble in cold dilute HCl.

Cobalt.

Symbol, Co. Atomic weight, 58.56. Valence, II.

The metal is similar to nickel, with a faint reddish tinge. The salts in the hydrous form are generally pink, in the anhydrous form, blue.

No official compounds.

Analytical reactions for Cobalt. Use $Co(NO_3)_2$ solution.

1.—NaOH precipitates $Co(OH)_2$, insoluble in excess. On boiling the precipitate becomes pink. The blue hydroxide becomes olive-green on standing.

2.—NH_4OH precipitates blue $Co(OH)_2$, soluble in excess.

3.—$(NH_4)_2S$ precipitates black CoS, insoluble in cold dilute HCl.

Manganese.

Symbol, Mn. Atomic weight, 54.6. Valence, II, IV.

Occurs in nature chiefly as the oxide, MnO_2.

Official compounds: Dioxide, Hypophosphite, Sulphate, Potassium Permanganate.

Manganese Dioxide, MnO_2. (Black Oxide of Manganese.) Found in nature and made also artificially. A fine black powder, odorless and tasteless, insoluble in water or alcohol. Used in the preparation of chlorine and of oxygen.

Manganese Sulphate, $MnSO_4.4H_2O$. Colorless or rose-colored prisms, slightly bitter, astringent taste, slightly efflorescent in air. Soluble in water, insoluble in alcohol.

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POTASSIUM PERMANGANATE, $KMnO_4$. Prismatic, dark-purple crystals, permanent in air, soluble in 15 parts water. Decomposes with alcohol, a strong oxidizing agent.

Analytical Reactions. Use solution of $MnSO_4$.

1.—NaOH, or NH_4OH, precipitates whitish manganous hydroxide, $Mn(OH)_2$, turning brown and oxidizing on exposure to the air to $Mn(OH)_3$. The precipitation by NH_4OH is prevented by the presence of NH_4Cl.

2.—$(NH_4)_2CO_3$ precipitates white $MnCO_3$, soluble in excess, but reprecipitating on boiling.

3.—$(NH_4)_2S$, precipitates flesh-colored manganous sulphide, MnS.

4.—Fused with a mixture of KNO_3 and Na_2CO_3, on platinum foil, green potassium and sodium manganates are formed.

5.—Borax bead in oxidizing flame is violet when hot, reddish-violet when cold. In reducing flame the bead is colorless.

ZINC.

Symbol, Zn. Atomic weight, 64.9. Valence, II.

Occurs in nature as the carbonate, silicate, and sulphide. A bluish-white metal, with crystalline structure.

Official compounds: Acetate, Bromide, Carbonate, Chloride, Iodide, Oxide, Phenolsulphonate, Stearate, Sulphate, Valerate.

ZINC OXIDE, ZnO. A fine amorphous, white or yellowish-white, odorless and tasteless, powder. Absorbs carbon dioxide from the air; insoluble in water or in alcohol.

ZINC CARBONATE, $2\,ZnCO_3.3Zn(OH)_2$. A very fine, impalpable powder, odorless and tasteless, permanent in air, insoluble in water or in alcohol.

ZINC CHLORIDE, $ZnCl_2$. A white, granular, odorless powder, with strong caustic properties, very deliquescent, soluble in water and in alcohol.

ZINC SULPHATE, $ZnSO_4.7H_2O$. (White Vitriol.) Colorless crystals or a granular crystalline powder, odorless, with astringent metallic taste. Efflorescent in dry air. Soluble in water, insoluble in alcohol.

Analytical Reactions. Use solution of $ZnSO_4$, or $ZnCl_2$.

1.—NaOH, added carefully, precipitates zinc hydroxide, $Zn(OH)_2$, easily soluble in excess.

$$ZnCl_2 + 2NaOH = Zn(OH)_2 + 2NaCl.$$

$$Zn(OH)_2 + 2NaOH = Na_2ZnO_2 + 2H_2O.$$

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2.—NH_4OH precipitates white $Zn(OH)_2$, soluble in excess.

3.—$(NH_4)_2S$ precipitates white zinc sulphide, ZnS, insoluble in $HC_2H_3O_2$, soluble in dilute HCl.

4.—$NaCO_3$ precipitates white, basic carbonate, $2ZnCO_3 . 3Zn(OH)_2$, insoluble in excess.

5.—Borax bead in oxidizing flame is clear and yellow; colorless on cooling, or enamel-like if present in excess.

Separation and Analysis of Group IV. Metals.

Into the clear, warm filtrate from Group III add H_2S as long as a precipitate is formed. Filter. Save filtrate for Group V. Precipitate CoS, black; NiS, black; MnS, pink; ZnS, white. Treat precipitate with cold, dilute HCl.

<table>
<tr>
<td>Residue, CoS, NiS, black.
Dissolve a portion in nitrohydrochloric acid, evaporate nearly to dryness, add $NaHCO_3$ solution and a little H_2O_2, warm gently and filter. A green colored filtrate indicates cobalt.
Test other portions of residue with borax bead. Cobalt gives a blue bead; nickel gives a brown bead.</td>
<td>Solution, $MnCl_2$, $ZnCl_2$.
Boil for several minutes, cool, add excess of NaOH, filter and wash.
<table>
<tr>
<td>Precipitate $Mn(OH)_2$, pink; add a little Pb_3O_4 and 10 c.c. dilute HNO_3; warm very gently; filter. A pink filtrate indicates manganese.</td>
<td>Solution, Na_2ZnO_2.
Add H_2S—a white precipitate indicates zinc.</td>
</tr>
</table>
</td>
</tr>
</table>

Group V.

Barium, Strontium, Calcium, Magnesium.

Barium.

Symbol, Ba. Atomic weight, 136.4. Valence, II.

No official compounds. Common reagents are the Chloride, $BaCl_2.2H_2O$, the Oxide, BaO (Baryta), the Dioxide, BaO_2, and the Carbonate, $BaCO_3$.

Analytical Reactions. Use $BaCl_2$ solution.

1.—$(NH_4)_2CO_3$ precipitates white barium carbonate, $BaCO_3$.

2.—H_2SO_4 and soluble sulphates precipitate white barium sulphate, $BaSO_4$, insoluble in HCl.

3.—Na_2HPO_4 precipitates white barium phosphate, $BaHPO_4$, soluble in $HC_2H_3O_2$.

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4.—K_2CrO_4 or $K_2Cr_2O_7$ precipitates yellow barium chromate, $BaCrO_4$, insoluble in dilute $HC_2H_3O_2$ but soluble in HCl.

5.—Barium compounds impart a green color to the flame.

Strontium.

Symbol, Sr. Atomic weight, 86.94. Valence, II.

Official compounds: Bromide, Iodide, Salicylate. The Bromide, $SrBr_2$, and the Iodide, SrI_2, form colorless, odorless, hexagonal crystals of saline taste, soluble in water and in alcohol.

Analytical Reactions. Use solution of $SrCl_2$.

1.—$(NH_4)_2CO_3$ precipitates white strontium carbonate, $SrCO_3$.

2.—H_2SO_4 and soluble sulphates precipitate white strontium sulphate, $SrSO_4$.

3.—K_2CrO_4 precipitates slowly from strong alkaline solutions, yellow strontium chromate, $SrCrO_4$, soluble in $HC_2H_3O_2$. $K_2Cr_2O_7$ gives no precipitate.

4.—Strontium compounds impart an intense red or crimson color to the flame.

Calcium.

Symbol, Ca. Atomic weight, 39.8. Valence, II.

Official compounds: Bromide, Carbonate, Chloride, Chlorinated lime, Hydroxide, Hypophosphite, Lactophosphate, Oxide, Phosphate, Sulphate, Sulphide (Sulphurated lime).

Calcium Oxide, CaO. (Calx, Lime.) Prepared by calcining marble. Hard, white or grayish-white, odorless masses with caustic taste. Absorbs moisture and carbon dioxide from the air, breaking down to a white powder. Soluble in 760 parts water at 25° C., in 1600 parts boiling water, insoluble in alcohol.

Calcium Hydroxide, $Ca(OH)_2$. Prepared by slaking the oxide with water. *Lime Water* is a solution of the hydroxide (0.14 per cent.) in water. It is a clear, colorless liquid, of alkaline taste, absorbing carbon dioxide on exposure to air.

Calcium Carbonate, $CaCO_3$. A fine white, odorless and tasteless powder, permanent in air, soluble in acids with effervescence, slightly soluble in water containing ammonium salts or carbon dioxide. *Precipitated Calcium Carbonate* is prepared by adding a hot solution of sodium carbonate to a solution of calcium chloride. *Prepared Chalk* (*Creta Preparata*) is the native carbonate freed from most of its impurities by elutriation.

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CALCIUM CHLORIDE, $CaCl_2$. A white, deliquescent, soluble substance with sharp saline taste.

CHLORINATED LIME, $CaOCl_2$. (Bleaching Powder.) A grayish-white powder, made by action of chlorine on calcium hydroxide. On solution in water the hypochlorite, $Ca(OCl)_2$, and chloride are formed. Exposed to air the carbonate is formed and chlorine gas is given off.

CALCIUM SULPHATE, $CaSO_4$. Occurs in nature as gypsum, $CaSO_4.2H_2O$, which, carefully heated until it has lost three-fourths of its water, forms the Exsiccated Calcium Sulphate of the U. S. P. This, mixed with one-half its weight of water, forms a paste, which hardens to a firm cement.

Analytical Reactions. Use $CaCl_2$ solution.

1.—$(NH_4)_2CO_3$ precipitates white calcium carbonate, $CaCO_3$ from ordinary but not from highly dilute solutions.

2.—From strong solutions H_2SO_4 precipitates white calcium sulphate. Soluble in excess of water and in boiling ammoniacal $(NH_4)_2SO_4$.

3.—Na_2HPO_4 precipitates white calcium phosphate, $CaHPO_4$, soluble in $HC_2H_3O_2$.

4.—$(NH_4)_2C_2O_4$ precipitates white calcium oxalate, CaC_2O_4, soluble in HCl but insoluble in $HC_2H_3O_2$.

5.—Calcium compounds impart a yellowish-red color to the flame.

MAGNESIUM.

Symbol, Mg. Atomic weight, 24.18. Valence, II.

A silver-white metal tarnishing rapidly on exposure to air, burns at a red heat with a bright white light.

Official compounds: Carbonate, Citrate, Oxide, Sulphate.

MAGNESIUM OXIDE, MgO. (Magnesia.) Made by calcining magnesium carbonate. A light, amorphous, almost tasteless powder. With water it forms the gelatinous hydroxide. Milk of Magnesia is water with the hydroxide in suspension. Heavy Magnesia, also MgO, differs only in density from the above.

MAGNESIUM CARBONATE, $4MgCO_3.Mg(OH)_2.5H_2O$. (Magnesia alba.) A bulky white powder with earthy taste, practically insoluble in water. Effervesces with acids.

MAGNESIUM SULPHATE, $MgSO_4.7H_2O$. (Epsom Salts.) Small needle-like crystals, with cooling, saline, and bitter taste, slowly

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efflorescent in air. Soluble in 0.85 parts water, insoluble in alcohol.

Analytical Reactions. Use solution of $MgCl_2$.

1.—$(NH_4)_2CO_3$ precipitates, slowly from strong solutions, white magnesium carbonate $MgCO_3$. The precipitate is hastened by warming but prevented by presence of NH_4Cl.

2.—NH_4OH precipitates part of the magnesium as $Mg_2(OH_2$, but the precipitation is prevented by presence of NH_4Cl, and, also, by too great dilution. NaOH gives a more complete precipitation.

3.—Na_2HPO_4 in presence of NH_4Cl and NH_4OH, precipitates crystalline NH_4MgPO_4. In dilute solutions the precipitate forms slowly.

4.—Neither H_2SO_4 nor K_2CrO_4 precipitates salts of magnesium.

Separation and Analysis of Group V Metals.

To filtrate from group IV add NH_4OH and $(NH_4)_2CO_3$. Filter, wash well.

<table>
<tr><td colspan="2">Ppt. $BaCO_3$, $CaCO_3$ and $SrCO_3$, white. Dissolve in a very little dilute $HC_2H_3O_2$. Add $K_2Cr_2O_7$, filter and wash.</td><td rowspan="2">Solution contains magnesium and Group six.
Add Na_2HPO_4, a white granular precipitate indicates Magnesium.
The filtrate contains metals of group six, but they are more conveniently tested for from original solution.</td></tr>
<tr><td>Ppt. $BaCrO_4$ yellow.
Soluble in HCl, and solution forms white ppt. with H_2SO_4.
The acid solution will impart a green flame to platinum wire.</td><td>Solution $Sr(C_2H_3O_2)_2Ca(C_2H_3O_2)_2$.
The red color due to excess of $K_2Cr_2O_7$ may be eliminated by reprecipitating with $(NH_4)_2CO_3$, washing, and then dissolving in a little dilute acetic acid.
Divide solution in two parts:

Part 1. Test for *Strontium* by boiling with an equal volume of saturated $CaSO_4$ solution. A white ppt. is formed after cooling.

Part 2. Add K_2SO_4 and boil, cool, filter. Add $(NH_4)_2C_2O_4$ = a white ppt. insoluble in $HC_2H_3O_2$, soluble in HCl, if Calcium is present.</td></tr>
</table>

Group VI.

Sodium, Potassium, Lithium, Ammonium.

Sodium.

Symbol, Na. Atomic weight, 22.88. Valence, I.

Chief occurrence in nature as the chloride. The metal is pre-

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pared by electrolysis of the fused hydroxide or by heating the carbonate with carbon. It is soft, silvery-white, with a strong affinity for oxygen, decomposes water, setting free hydrogen.

Official compounds: Acetate, Arsenate, Benzoate, Bicarbonate, Bisulphite, Borate, Bromide, Carbonate, Chlorate, Chloride, Citrate, Hydroxide, Hypophosphite, Iodide, Nitrate, Nitrite, Phenolsulphonate, Phosphate, Pyrophosphate, Salicylate, Sulphate, Sulphite, Thiosulphate.

SODIUM MONOXIDE, Na_2O. SODIUM DIOXIDE, Na_2O_2.

SODIUM HYDROXIDE, NaOH. (Caustic Soda.) Prepared by boiling a solution of sodium carbonate and calcium hydroxide. A white brittle substance, absorbing moisture and carbon dioxide on exposure to air, soluble in 1 part of water and very soluble in alcohol forming strongly alkaline solutions.

SODIUM CARBONATE, Na_2CO_3. (Sal Soda, Washing Soda.) The pharmacopœial preparation is the monohydrated salt, $Na_2CO_3.H_2O$. This is a white granular powder, very slightly deliquescent at the ordinary temperature, effloresces at 50° C. and loses its water of crystallization at 100° C. Soluble in 2.9 parts water, forming an alkaline solution which effervesces with acids. Insoluble in alcohol.

SODIUM BICARBONATE, $NaHCO_3$. Made by the action of carbon dioxide on the monohydrated normal salt. A white powder of slightly alkaline taste, soluble in 12 parts of water at 15° C. At higher temperatures carbon dioxide is driven off and the salt reverts to the normal carbonate. Solutions effervesce with acids.

SODIUM CHLORIDE, NaCl. The chief occurrence of sodium in nature. Colorless, cubical crystals, or crystalline powder, soluble in 2.8 parts of water at 25°, almost insoluble in alcohol.

SODIUM HYPOCHLORITE, NaClO. The chief constituent of the U. S. P. solution of chlorinated soda.

SODIUM HYPOBROMITE, NaBrO. Reagent for urea.

SODIUM NITRATE, $NaNO_3$. (Chili Saltpeter.) Colorless, hygroscopic crystals, with cooling, saline, and slightly bitter taste. Soluble in 1.1 parts water and in about 100 parts alcohol.

SODIUM PYROPHOSPHATE, $Na_4P_2O_7.10H_2O$. Crystalline powder; odorless, and having a feebly alkaline taste. Soluble in 11.5 parts of water.

SODIUM PHOSPHATE, $Na_2HPO_4.12H_2O$. Colorless crystals or white granular powder with cooling, saline taste. On exposure to

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air it loses gradually 5 molecules of water. Soluble in 5.5 parts of water, insoluble in alcohol.

SODIUM SULPHATE, $Na_2SO_4.10H_2O$. (Glauber's Salt.) Large colorless crystals, efflorescent, soluble in water, insoluble in alcohol.

SODIUM THIOSULPHATE, $Na_2S_2O_3.5H_2O$. Formerly known as "hyposulphite." Colorless crystals, soluble in water, insoluble in alcohol, permanent in dry air at ordinary temperature, used as a solvent for the halogen salts of silver, and in medicine.

Analytical Reactions. Use solution of NaCl.

1.—Test on platinum wire, in Bunsen flame; observe the bright yellow color developed.

2.—Neither $PtCl_4$ nor $H_2C_4H_4O_6$ gives a precipitate with sodium salts. Compare Potassium and Ammonium.

POTASSIUM.

Symbol, K. Atomic weight, 38.86. Valence, I.

The metal resembles sodium closely. In the decomposition of water the hydrogen set free ignites with the heat of the reaction. Official compounds: Acetate, Arsenite, Bicarbonate, Bitartrate, Bromide, Carbonate, Chlorate, Citrate, Cyanide, Dichromate, Potassium and Sodium tartrate, Ferrocyanide, Hydroxide, Hypophosphite, Iodide, Nitrate, Permanganate, Sulphate.

POTASSIUM HYDROXIDE, KOH. (Caustic Potash.) Made by boiling a solution of the carbonate with calcium hydroxide. A hard, white, brittle substance, absorbing moisture and carbon dioxide from the air. Soluble in 0.4 part water and in 2 parts alcohol, forming strongly alkaline solutions.

POTASSIUM CARBONATE, K_2CO_3. (Salt of Tartar.) May be prepared from wood ash and from the chloride. A white, granular, deliquescent powder, very soluble in water, insoluble in alcohol. Solutions effervesce with acids.

POTASSIUM BICARBONATE, $KHCO_3$. Made by passing carbon dioxide through a solution of the carbonate. Crystalline powder, permanent in air, soluble in 3 parts water, almost insoluble in alcohol. Solutions effervesce with acids.

POTASSIUM CHLORATE, $KClO_3$. Colorless, pearly, plate-like crystals, soluble in 16 parts water, permanent in air. A strong oxidizing agent. Do not triturate with organic matter.

POTASSIUM NITRATE, KNO_3. (Nitre, Saltpeter.) Made by the

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reaction between sodium nitrate and potassium chloride. Prismatic crystals of cooling, saline taste, slightly hygroscopic in moist air. Soluble in 3.6 parts water, very sparingly soluble in alcohol. A strong oxidizing agent.

POTASSIUM BROMIDE, KBr. White cubical crystals of saline taste, soluble in 1.7 parts water and in 12.5 parts alcohol.

POTASSIUM IODIDE, KI. Similar to the bromide, soluble in 0.7 parts water and in about 12 parts alcohol.

Analytical Reactions. Use KCl solution.

1.—Test on clean platinum wire, in Bunsen flame, observe the violet color developed. In the presence of sodium compounds the yellow rays produced thereby may be excluded by the use of blue glass.

2.—HCl_4 precipitates from solutions of potassium salts yellow crystalline, potassium platinic chloride, K_2PtCl_6, soluble in excess of water, and in alkalies but insoluble in acids or in alcohol.

3.—$H_2C_4H_4O_6$, and $NaHC_4H_4O_6$ precipitate from concentrated neutral solutions of potassium salts, white, crystalline, potassium hydrogen tartrate, $KHC_4H_4O_6$.

LITHIUM.

Symbol, Li. Atomic weight, 6.98. Valence, I.

A soft silvery-white metal, sp. gr. 0.589, oxidizing on exposure to air. Official compounds: Benzoate, Bromide, Carbonate, Citrate and Salicylate.

LITHIUM CARBONATE, Li_2CO_3. A light, odorless, white powder of alkaline taste, soluble in 75 parts of water at 25° C.

Analytical Reactions. Use solution of LiCl.

1.—Lithium compounds color the non-luminous flame crimson, or carmine-red.

2.—Na_2HPO_4 precipitates from hot solutions of lithium salts, lithium phosphate, Li_3PO_4, best after addition of NaOH.

3.—Na_2CO_3 precipitates from cold concentrated solutions Li_2CO_3, soluble in 75 parts of water.

4.—$PtCl_4$ and $H_2C_4H_4O_6$ give no precipitates.

AMMONIUM.

Radical, (NH_4). Molecular weight, 17.93. Valence, I.

Official compounds: Acetate, Benzoate, Bromide, Carbonate, Chloride, Iodide, Salicylate, Sulphate, Valerate.

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AMMONIUM HYDROXIDE, NH_4OH. (Ammonia Water.) A solution of ammonia gas, NH_3 (10 p. c. by weight) in water. Sp. gr. 0.958 at 25° C. Stronger ammonia water, U. S. P. contains 28 p. c. NH_3. Sp. gr. 0.897 at 25° C.

AMMONIUM CARBONATE, U. S. P.—$NH_4HCO_3.NH_4NH_2CO_2$. Hard, white, translucent masses with odor of ammonia and sharp saline taste.

On exposure to air the salt becomes opaque and slowly crumbles to a white powder of the acid carbonate, NH_4HCO_3. Soluble slowly in 4 parts water, the carbamate, $NH_4NH_2CO_2$ uniting with a molecule of water to form the normal carbonate $(NH_4)_2CO_3$. On addition of ammonia water the NH_4HCO_3 also changes to the normal salt. Ammonium carbonate is easily recognized by its odor and by its effervescence with acids.

Spirit of Ammonia consists of about 10 per cent. of ammonia gas dissolved in alcohol.

Aromatic Spirit of Ammonia is a solution of the carbonate in dilute ammonia water with the addition of alcohol, and the oils of lemon, lavender, and nutmeg.

AMMONIUM CHLORIDE, NH_4Cl. (Sal Ammoniac.) Prepared by adding hydrochloric acid to a solution of ammonia. A white, odorless, crystalline powder with cooling saline taste, permanent in air. Soluble in 2 parts water and in 50 parts alcohol.

Analytical Reactions. Use NH_4OH, and $(NH_4)_2SO_4$ solution.

1.—Note odor.

2.—Note the action of the fumes on red litmus paper.

3.—Upon one watch-glass place a drop of NH_4OH, upon the other a drop of HCl. Observe the white fumes of NH_4Cl produced when the glasses are brought together.

4.—Test a solution of $(NH_4)_2SO_4$. Note that no odor is given off. Add a few drops of NaOH, and heat. Note characteristic odor of ammonia.

5.—$PtCl_4$ and $H_2C_4H_4O_6$ produce precipitates with ammonium salts resembling those produced from solutions of potassium compounds.

TESTS FOR GROUP VI.

Dip the loop of a clean platinum wire into the original solid or solution to be tested and hold in the non-luminous flame of a Bunsen burner. A prominent yellow color is imparted to the

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flame if sodium is present. If potassium be present alone, a characteristic violet color is obtained, but when both sodium and potassium are present the color due to the potassium will be obscured unless the flame is viewed through a double blue glass.

Lithium will impart a transient bright red color to the flame. Strontium may interfere, but usually the red color produced by strontium is more permanent.

A little careful practice with known salts of these metals will enable the student to become quite proficient in recognizing them.

Ammonium salts are tested for by adding a solution of sodium hydroxide to the sample and gently heating—the odor of ammonia is quite readily recognized, or the gas may be conducted into a tube of water containing a few drops of Nessler's solution. A brownish color indicates the presence of ammonia.

Examination of a Solution Known to Contain but One Metal.

1.—Add dilute HCl. Precipitate: Soluble on heating with water = **Pb.** Insoluble in water, add NH_4OH; it turns black = **Hg**(ous); it dissolves = **Ag.**

2.—Pass H_2S through the slightly acid solution. Precipitate: Soluble in $(NH_4)_2S$ — yellowish = **As, Sn**(ic); orange = **Sb;** black or brownish-black = **Sn**(ous), **Au, Pt.** Insoluble in $(NH_4)_2S$ — yellow = **Cd;** black = **Cu, Hg**(ic), **Pb, Bi.**

3.—Add NH_4Cl and NH_4OH to original solution. Precipitate: Reddish-brown = **Fe**(ic); greenish = **Cr** (Fe(ous)); white = **Al.**

If phosphates are present add to the original NH_4OH and then $HC_2H_3O_2$ to acid reaction. Boil the mixture.

(*a*) A precipitate forms — filter, wash into a test-tube, add NaOH and boil. Reddish residue = Fe. Greenish residue = Cr. No residue, but a precipitate is obtained by boiling with NH_4Cl = Al.

(*b*) No precipitate forms — test with K_2CrO_4, a ppt = Ba. Add dilute H_2SO_4, a ppt = Sr. Add $(NH_4)_2C_2O_4$, a ppt = Ca. Cool, add excess of NH_4OH, a ppt = Mg or Mn. Test the precipitate by Test 4, page 49.

If organic acids are present these must be destroyed before testing under 3. Evaporate the solution to dryness, ignite the residue, and redissolve in water acidulated with HCl.

4.—To solution not precipitated by NH_4Cl and NH_4OH, add $(NH_4)_2S$. Precipitate: Flesh-tint = **Mn;** dirty-white = **Zn;** black = **Ni, Co.**

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5.—Add $(NH_4)_2CO_3$, or, to the original solution add NH_4Cl, $(NH_4)_2CO_3$, and NH_4OH. Precipitate = Ba, Sr, Ca. Filter. dissolve in dilute $HC_2H_3O_2$, and divide this solution into 2 parts.

(*a*) Add solution of $CaSO_4$. Precipitate: Ba (ppt. forms at once), Sr (ppt. forms slowly).

(*b*) If a precipitate was obtained in (*a*) add $K_2Cr_2O_7$. Precipitate = **Ba.** No precipitate is formed with $K_2Cr_2O_7$ = **Sr.**

(*c*) No precipitate was obtained in (*a*), add $(NH_4)_2C_2O_4$ and NH_4OH. Precipitate = **Ca.**

6.—If $(NH_4)_2CO_3$ gives no precipitate add Na_2HPO_4. Precipitate = **Mg.**

7.—No precipitate having been obtained by any of the preceding reagents, test the original for **Li, Na** and **K** by the flame, and for $\mathbf{NH_4}$, by heating with NaOH. (See page 57.)

ANALYTICAL SCHEME FOR METALS.

The tests given above are practical only when a solution is known to contain but *one* metal. They are, therefore, of no real value outside of laboratory exercises. The scheme given on the following page, however, is applicable to all mixtures and compounds of the more usual metals met with in practice.

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OUTLINE OF MANIPULATIONS USED IN TESTING AN UNKNOWN SOLUTION FOR METALS.

To solution to be analyzed add HCl, drop by drop, as long as a precipitate is formed. Filter. Save filtrate.

To filtrate from above add H_2S as long as a precipitate is formed. Filter. Save filtrate.

RESIDUE.
Group I.
$PbCl_2$, white.
$AgCl$, white.
$HgCl$, white.

Wash residue with cold water and discard the washings.
Add hot water to dissolve $PbCl_2$.
Test for lead in each. (1) H_2S = black. (2) KI = yellow. (3) H_2SO_4 = white. (4) K_2CrO_4 = yellow.
Add NH_4OH. This will dissolve AgCl and turn HgCl black.
Add HNO_3 to solution *till acid*. A white precipitate will be formed if silver is present.

Wash residue with hot water and discard washings.
Transfer to evaporating dish and mix well with yellow ammonium sulphide at 60° C. Filter. Portion A is dissolved.

To FILTRATE containing Portion A, add HCl. Precipitate is As_2S_3, Sb_2S_3 and SnS. Collect precipitate on filter paper and wash with hot water, discard washings. Transfer to evaporating dish, add HCl and a crystal of $KClO_3$, boil till nearly evaporated, add a little water, filter and add to Marsh apperatus, passing gas into dilute silver nitrate solution. Filter silver nitrate solution, and if there is a black precipitate test it for antimony by dissolving in HCl, evaporating excess, adding water, filtering, and adding H_2S. Orange precipitate indicates antimony. Add HCl to silver nitrate, filtrate to ppt. silver, filter to perfectly clear, and test for arsenic by adding H_2S, which gives a yellow precipitate with arsenic.

Any tin that may be present will be deposited on zinc in Marsh apparatus. Test for tin by dissolving the zinc in HCl, filtering, and adding $HgCl_2$—a dirty white precipitate indicates tin. Use also special test on original solution.

The RESIDUE, consisting of Portion B, should be washed with hot water and washings discarded Transfer to evaporating dish and boil with HNO_3 1 part, water 2 parts; filter. If there is any residue, dissolve it in nitrohydrochloric acid, evaporate to nearly dryness, add a little water and filter. Test for mercury by adding H_2S. Add a few drops of H_2SO_4 to solution, and if lead is present a white precipitate will be formed. Filter and test precipitate on filter paper with a drop of KI. A yellow color indicates lead. Add NH_4OH to solution till alkaline, and if bismuth is present a white precipitate will be formed. Filter and test precipitate on filter paper with a drop of *fresh* K_2SnO_2. Divide the solution into three parts. Make one portion acid with acetic acid, then add $K_4Fe(CN)_6$; a brown precipitate indicates copper. To second portion add H_2S; a yellow precipitate indicates cadmium. If H_2S gives a black precipitate, add acetic acid to third portion till acid, then about 5 c.c. of KCN, then a very little H_2S; this manipulation prevents the interference of copper with the test for cadmium.

A { As_2S_3, yellow. Sb_2S_3, orange. SnS, brown.
B { HgS, black. PbS, black. Bi_2S_3, black. CuS, black. CdS, yellow.

RESIDUE.
Group III.
$Fe(OH)_3$, brown.
$Cr(OH)_3$, green.
$Al(OH)_3$, white.

Boil with NaOH, filter, neutralize filtrate with HCl, then add Na_2CO_3; a white precipitate indicates aluminium. Dissolve a portion of the residue in HCl, filter, and test for iron with KCNS.

Fuse remainder of residue with KNO_3 and Na_2CO_3 on platinum foil, dissolve in hot water and filter. Add acetic acid till acid reaction, then $Pb(C_2H_3O_2)_2$; a yellow precipitate indicates chromium.

Boil filtrate, add a few drops of HNO_3 and again boil. Add 10 c.c. of NH_4Cl and sufficient NH_4OH to make alkaline. Filter, and save filtrate.

RESIDUE.
Group IV.
CoS, black.
NiS, black.
MnS, pink.
ZnS, white.

Wash with hot water and discard washings.
Add cold, dilute HCl (1–4). This will dissolve MnS and ZnS.
Test residue with borax bead. Cobalt = blue, nickel = brown.
Add KOH to solution till strongly alkaline and boil; filter.
Test filtrate for zinc by adding H_2S = white. Transfer residue to evaporating dish, add Pb_3O_4 and HNO_3, warm *gently*. Filter. If filtrate is red, manganese is present.

Add H_2S as long as a precipitate is formed. Filter, and save filtrate.

RESIDUE.
Group V.
$BaCO_3$, white.
$CaCO_3$, white.
$SrCO_3$, white.

Dissolve residue in a few drops of $HC_2H_3O_2$; add 10 c.c. water, then $K_2Cr_2O_7$; filter. Test ppt. for barium, after washing, by dissolving in HCl, and adding a drop of H_2SO_4 = white ppt. Add $(NH_4)_2CO_3$ to filtrate, filter and wash; discard washings. Dissolve ppt. in a few drops $HC_2H_3O_2$ and add 10 c.c. water. Divide in two portions. No. 1, test for strontium by adding an equal volume of saturated $CaSO_4$ solution. A white ppt. indicates strontium. No. 2, add K_2SO_4 and boil, cool and filter; add a few drops of $(NH_4)_2C_2O_4$. A white ppt. insoluble in $HC_2H_3O_2$, but soluble in HCl indicates calcium.

Add $(NH_4)_2CO_3$ to filtrate. Filter, and save filtrate.

To filtrate add $(NH_4)_2CO_3$ and $(NH_4)_2SO_4$. If ppt. is formed, filter, and to clear filtrate add $(NH_4)_2HPO_4$. Ppt. = $Mg(NH_4)PO_4$, white.

Sodium, potassium and lithium may be tested for in filtrate from magnesium by means of the flame tests, but it is better to use the flame tests with the original solution or solid specimen.

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TESTS FOR THE COMMON ACIDS.

After it has been determined what metals are present the acid radicals may be tested for separately in accordance with the following special tests:

Acetic Acid, $HC_2H_3O_2$, and Acetates.

1.—Note the characteristic odor of the acid.

2.—*Neutral* $FeCl_3$ added to solutions of *neutral acetates* gives a dark red color, destroyed by addition of either HCl, or $HgCl_2$. When the solution is acid, neutralize carefully with very dilute ammonia water.

3.—Warmed with a few drops of H_2SO_4 and the same of alcohol, and the characteristic odor of ethyl acetate, $C_2H_5(C_2H_3O_2)$, is developed.

4.—With acetates the odor of acetic acid is developed by warming with sulphuric acid.

Boric Acid, H_3BO_3, and Borates.

1.—Solutions of the crystalline acid in glycerine burn with a green flame.

2.—Solutions of the acid turn litmus paper red. Turmeric paper is at first unchanged, but on drying becomes reddish-brown. A drop of ammonium hydroxide placed on the dried turmeric paper gives a bluish-black spot.

Sodium tetraborate, $Na_2B_4O_7$, (Sodium borate, U. S. P., or borax.) Burns with the yellow flame of sodium, and has an alkaline reaction with litmus paper. The green boric acid flame can be obtained by mixing the borax with a few drops of H_2SO_4 and a little alcohol. Upon ignition the alcohol will burn with a green mantle. A concentrated solution of borax warmed with $CaCl_2$ and a little NH_4OH, gives a precipitate of calcium borate, soluble in $HC_2H_3O_2$ and in excess of water.

Carbonic Acid, H_2CO_3, and Carbonates.

1.—Acids, such as HCl, produce an effervescence of CO_2 gas.

2.—$Ca(OH)_2$ and $Ba(OH)_2$ precipitate white $CaCO_3$, and $BaCO_3$, soluble in acids with effervescence.

3.—The CO_2 given off in effervescence is colorless and practically odorless—it turns blue litmus paper red, but the blue color is restored on drying and warming. Passed into lime water the gas produces a white precipitate which redissolves with excess of the gas.

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Chromic Acid, H_2CrO_4, and Chromates.

1.—H_2S gas, in acid solutions, produces a green color, due to formation of chromic oxide, and sulphur is precipitated.

2.—$AgNO_3$ precipitates dark red Ag_2CrO_4, soluble in nitric acid and in ammonium hydroxide.

3.—Treated with an excess of H_2SO_4 and shaken with an ethereal solution of H_2O_2, a fine blue color is produced.

4.—$HgNO_3$ precipitates dark red Hg_2CrO_4.

5.—Chromates warmed with conc. H_2SO_4, give off oxygen; with hydrochloric acid, give off chlorine.

Dichromates (of alkali metals), *e. g.*, $K_2Cr_2O_7$. Tests are similar to those above. Test 3 is best performed as follows: To water in a test-tube add a few drops of H_2O_2, acidify with one or two drops of HCl, add a little ether and then one or two drops of the dichromate. The ethereal layer is colored blue.

Citric Acid, $H_3C_6H_5O_7$, and Citrates.

1.—$CaCl_2$ precipitates from boiling solutions of citrates, white calcium citrate, $Ca_3(C_6H_5O_7)_2$, soluble in $HC_2H_3O_2$, insoluble in NaOH, soluble in cold NH_4Cl, but reprecipitated by boiling. In testing the free acid first nearly neutralize the solution by addition of dilute ammonium hydroxide, then add the $CaCl_2$ and boil.

2.—Add sufficient $Ca(OH)_2$ to make the solution alkaline; the solution remains clear, clouds on boiling, and clears again on cooling.

3.—$AgNO_3$ produces with normal alkali citrates a white flocculent precipitate of silver citrate, $Ag_3C_6H_5O_7$. On long boiling, a partial separation of silver occurs. The precipitate dissolved in NH_4OH, and boiled, forms no mirror (unlike the tartrate).

4.—Heated on platinum foil, citric acid fuses, carbonizes, and gives off pungent fumes, but no odor of burnt sugar (difference from tartaric acid).

5.—Heated with conc. H_2SO_4 citrates are charred and a colorless gas is given off.

Hydriodic Acid, HI, and Iodides.

1.—$AgNO_3$ precipitates yellow silver iodide, AgI, insoluble in HNO_3 or in NH_4OH.

2.—$HgNO_3$ precipitates greenish-yellow mercurous iodide, HgI.

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3.—$HgCl_2$ precipitates red mercuric iodide, HgI_2.

4.—Add a few drops of "Chlorine water," and then a little starch paste. A blue color is developed which disappears when the solution is heated, but reappears when the solution is cooled. For free iodine the same test is used without the addition of chlorine water.

5.—Warmed with H_2SO_4, violet fumes of iodine are given off.

Hydrobromic Acid, HBr, and Bromides.

1.—$AgNO_3$ precipitates yellowish-white silver bromide, AgBr, insoluble in nitric acid, slowly soluble in strong, insoluble in dilute, ammonium hydroxide.

2.—$HgNO_3$ precipitates yellow mercurous bromide, HgBr.

3.—Add a little carbon disulphide, CS_2, and then a few drops of chlorine water. Mix well by shaking. The CS_2 acquires a reddish-yellow tint. (With iodides by the same test, the carbon disulphide is colored violet-red.)

4.—With starch paste and chlorine water a yellow color is developed.

5.—Warmed with H_2SO_4, brown fumes of bromine are evolved.

Hydrochloric Acid, HCl, and Chlorides.

1.—$AgNO_3$ precipitates curdy white silver chloride, AgCl, soluble in NH_4OH, insoluble in HNO_3.

2.—$HgNO_3$ precipitates white mercurous chloride, HgCl.

3.—$Pb(C_2H_3O_2)_2$ precipitates white crystalline lead chloride, $PbCl_2$, soluble in hot water.

4.—H_2SO_4 and MnO_2 warmed with the solution, liberate chlorine gas.

5.—Warmed with H_2SO_4, chlorides give off colorless fumes of HCl.

Chloric Acid and Chlorates: 1. Warmed with H_2SO_4, $KClO_4$ is formed and yellowish-green fumes of Cl_2O_4 are given off. Odor and bleaching power of Cl. Use care in test. Warmed with HCl there is less danger of explosion; Cl and Cl_2O_4 are given off. 2.—$AgNO_3$ gives no precipitate. 3.—Heated on charcoal, chlorates deflagrate.

Hypochlorous Acid and Hypochlorites: 1.—Solutions bleach litmus. 2.—With $AgNO_3$ a precipitate of AgCl is *slowly* formed. 3.—Warmed with H_2SO_4, Cl gas is given off.

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Hydrocyanic Acid, HCN, and Cyanides.

1.—Note the characteristic odor.

2.—$AgNO_3$ precipitates white silver cyanide, AgCN, soluble in KCN, soluble in NH_4OH, and in boiling HNO_3, but insoluble in cold dilute HNO_3. *To obtain the reaction with cyanides*, such as KCN, add first a little HNO_3 to decompose the cyanide and then add the $AgNO_3$. The precipitate is distinguished from AgCl by its solubility in boiling HNO_3, and by the odor of HCN developed on warming with *dilute* sulphuric acid.

3.—Add a few drops of yellow ammonium sulphide and evaporate to dryness on the water-bath. To the residue add a drop of $FeCl_3$. A blood-red color is produced, or, if the black sulphide of iron forms, dissolve this in a drop of dil. HCl, and the red color will then become apparent.

4.—Add NaOH and a few drops of a solution of $FeSO_4$ which has been previously exposed to the air, warm gently, and acidify with HCl. Prussian blue will be formed if HCN be present.

5.—Add a few drops of picric acid to a solution of potassium cyanide, and warm. Dark red potassium isopurpurate is formed.

Nitric Acid, HNO_3, and Nitrates.

1.—If strong HNO_3 be boiled with copper filings, the acid is decomposed, red fumes of NO_2 are produced, and the liquid becomes green.

2.—Add an equal bulk of strong H_2SO_4. Cool the mixture and float over it a solution of $FeSO_4$. At the contact of the two liquids a brown ring will develop.

3.—A small quantity of the fluid added to a solution of *brucia* in concentrated H_2SO_4, develops a fine red color. (Chloric acid gives the same reaction.)

4.—Nitrates and nitric acid are reduced by a mixture of zinc and H_2SO_4, NH_3 being formed.

Nitrites: 1.—Warmed with H_2SO_4 red fumes are given off. (A nitrate, so treated, yields nearly colorless fumes.) 2.—Nitrous acid, and nitrites in presence of sulphuric acid, give a blue color with KI and starch paste. 3.—Floated over a solution of $FeSO_4$, a brown ring will form at the contact.

Oxalic Acid, $H_2C_2O_4$, and Oxalates.

1.—$CaCl_2$ precipitates white calcium oxalate, CaC_2O_4, soluble in HCl, insoluble in $HC_2H_3O_2$.

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2.—$AgNO_3$ precipitates white silver oxalate, $Ag_2C_2O_4$, soluble in hot concentrated HNO_3, and in NH_4OH.

3.—Oxalic acid added to a solution of $KMnO_4$ acidulated with dilute H_2SO_4, and warmed gently, completely removes the color.

4.—Oxalates, unlike citrates and tartrates, are not charred when heated with H_2SO_4, but CO and CO_2 are given off.

5.—Heated on platinum foil, oxalates turn gray, but do not carbonize. A carbonate is produced, soluble in acids with effervescence.

Permanganic Acid, $HMnO_4$, and Permanganates.

1.—Heated in a dry tube permanganates decrepitate with evolution of oxygen.

2.—Permanganates dissolve in water to a purple-red solution.

3.—Acidulate the aqueous solution with H_2SO_4 and pass H_2S gas. The solution is decolorized and sulphur precipitated.

4.—$(NH_4)_2S$ precipitates MnS with separation of sulphur.

Manganates (salts of H_2MnO_4, green in color), and *Permanganates* are decomposed by boiling with HCl. Chlorine gas is given off and a permanent manganous salt is produced. See tests on p. 49.

Phosphoric Acid, H_3PO_4, and Orthophosphates.

1.—Neutral $FeCl_3$ with $NaC_2H_3O_2$ precipitates yellowish-white ferric phosphate, $FePO_4$. Free mineral acids should be absent. For the preparation of neutral ferric chloride, see Appendix.

2.—$CaCl_2$ precipitates, from solutions of soluble phosphates, white calcium hydrogen phosphate, $CaHPO_4$, soluble in acetic acid. Solutions of the free acid are precipitated only after neutralization.

3.—$AgNO_3$ precipitates yellow silver phosphate, Ag_3PO_4, soluble in acetic acid and in ammonium hydroxide.

4.—Acidify strongly with nitric acid, warm the mixture and add ammonium molybdate $(NH_4)_2MoO_4$, a yellow precipitate of ammonium phospho-molybdate, $(NH_4)_3PO_4(MoO_3)_{10}2H_2O$, is obtained. Soluble in ammonium hydroxide.

5.—"Magnesia Mixture" precipitates white magnesium ammonium phosphate, $Mg(NH_4)PO_4$, soluble in all acids.

Phosphites: 1.—Warmed with $AgNO_3$ in presence of NH_4OH, metallic silver is

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separated. 2.—$CaCl_2$ gives a white precipitate. 3.—Magnesia mixture gives a precipitate from strong solutions.

Hypophosphites: 1.—On ignition, inflammable PH_3 is given off. 2.—$AgNO_3$ precipitates white silver hypophosphite, turning black on exposure. 3.—$(NH_4)_2MoO_4$ gives a blue precipitate. 4.—$CaCl_2$ gives no precipitate.

Pyrophosphates: 1.—$AgNO_3$ precipitates white silver pyrophosphate. 2.—$MgSO_4$ precipitates magnesium pyrophosphate, soluble in excess of the reagent. 3.—$(NH_4)_2MoO_4$ reacts very slowly, or not at all.

Metaphosphates: 1.—$AgNO_3$ precipitates white silver metaphosphate. 2.—$(NH_4)_2MoO_4$ causes no precipitate. 3.—Albumin forms a white precipitate.

Salicylic Acid, $HC_7H_5O_3$, and Salicylates.

1.—$FeCl_3$ in neutral solutions gives a deep violet color. (Compare with test for Phenol.)

2.—Bromine water produces a yellowish-white precipitate. (See also Phenol.)

3.—Add methyl alcohol and one-fourth volume of H_2SO_4; on warming, the odor of methyl salicylate ("Oil of Wintergreen") is developed.

4.—Sodium salicylate, added to a solution of copper sulphate, changes the blue color of the latter to a bright green.

Sulphuric Acid, H_2SO_4, and Sulphates.

1.—$BaCl_2$ precipitates white barium sulphate, $BaSO_4$, insoluble in boiling water or in hydrochloric acid.

2.—$Pb(C_2H_3O_2)_2$ precipitates white lead sulphate, $PbSO_4$, soluble only in hot concentrated acids.

Sulphides: 1.—Warmed with H_2SO_4, if acted upon at all, give off H_2S. 2.—Insoluble sulphides are decomposed by HNO_3 with separation of sulphur.

Sulphites: 1.—Warmed with H_2SO_4, yield SO_2. 2.—Sulphites decompose $AgNO_3$ with separation of Ag. Sulphurous acid first reddens, then bleaches litmus paper.

Thiosulphates (Hyposulphites): 1.—Warmed with H_2SO_4 yield H_2S, SO_2, and sulphur. 2.—$AgNO_3$ is decomposed with final precipitation of Ag_2S.

Tartaric Acid, $H_2C_4H_4O_6$, and Tartrates.

1.—$CaCl_2$ precipitates from solutions of tartrates, white calcium tartrate, $CaC_4H_4O_6.4H_2O$, soluble in $HC_2H_3O_2$. Soluble also in NaOH, from which solution it is reprecipitated on boiling. In testing the free acid first neutralize by addition of dilute ammonium hydroxide. The precipitation is hastened by shaking.

2.—From solutions of normal tartrates, $AgNO_3$ precipitates white silver tartrate, $Ag_2C_4H_4O_6$, which blackens on boiling. If,

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instead of boiling the mixture, the precipitate be filtered off and dissolved in a few drops of dilute NH_4OH, on boiling, a mirror of silver forms on the tube. (The tube must be absolutely clean.)

3.—A strong aqueous solution of the acid with a strong solution of potassium acetate, gives a white crystalline precipitate, soluble in alkalies and in mineral acids, insoluble in acetic acid.

4.—Heated on platinum foil, tartaric acid and tartrates fuse, carbonize, and give off the characteristic odor of burnt sugar.

5.—Heated with conc. H_2SO_4 tartaric acid is charred and SO_2, CO_2 and CO are given off.

GENERAL PLAN OF ANALYSIS.

Preliminary Examination.

Should the substance be in solution, evaporate to dryness and apply the following preliminary tests to the residue:

1.—*Heat a portion of the powdered substance on platinum foil:*—It darkens and chars, giving the odor of burnt sugar = tartrates, citrates, sugar, etc. It darkens slightly, leaving a residue of carbonate = oxalates. Proteins, etc., produce an odor resembling that of burning hair.

2.—*To a little of the powdered substance in a test-tube add a few drops of H_2SO_4.* Note results before and after warming:—*Colored gas*—Violet fumes = iodides; brown fumes = bromides; yellow-green fumes of Cl = hypochlorites; yellow Cl_2O_4 = chlorates; reddish-brown fumes = nitrites; nearly colorless but faintly reddish-brown fumes = nitrates. *Colorless gas*—Effervescence in the cold, no odor = carbonates; on heating, odor of H_2S = sulphides (H_2S may arise also from reduction of the H_2SO_4, *e. g.*, by an iodide); odor of SO_2 = sulphites; odor of SO_2 with separation of S = thiosulphates (hyposulphites); odor of HCN = cyanides; odor of $HC_2H_3O_2$ = acetates; acid fumes of HCl = chlorides; CO and CO_2, without carbonization = oxalates; CO alone = formates, ferrocyanides; CO_2 with carbonization = tartrates, citrates, malates; HF (try action on glass) = fluorides; O = chromates. Characteristic odors are obtained from benzoates, succinates, and valerates.

No gas—Sulphates, phosphates, silicates, borates, arsenites, arsenates, tungstates, molybdates, iodates, many oxides, etc.

3.—*Heat some of the powder gently in a Bunsen flame,* moisten with

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HCl and heat again. The flame is colored *yellow* by Na; *violet* by K; *crimson* by Sr; *carmine-red* by Li; *reddish-yellow* by Ca; *green* by Ba, B_2O_3, and Mo; *emerald-green* by Cu; *bluish-green* by some phosphates; *bluish* by As, Sb, Pb, $CuCl_2$ and $CuBr_2$.

4.—*Heat a small portion of the powdered substance in a dry ignition tube.* It *blackens*:—Organic compounds and certain salts of copper and cobalt. It *changes color*:—Yellow when hot, white when cold = ZnO and many zinc salts; yellow both hot and cold = lead oxide; red-brown when hot, pale yellow when cold = Bi_2O_3 and certain bismuth salts; red to black when hot, reddish-brown when cold = Fe_2O_3 and salts of iron: brown both hot and cold = cadmium salts; brown when hot, yellow when cold = SnO_2. It *fuses*:—Many alkaline and other salts, also tartaric and citric acids before charring. It *sublimes*:—The sublimate is—gray and easily rubbed into globules = Hg; white crystalline, the substance first melting = $HgCl_2$; sublimate yellow when hot, white when cold = HgCl; black, but red on rubbing = HgS; steel-gray, odor of garlic = As; white octahedral crystals = As_2O_3; nearly black when hot, reddish-yellow when cold = As_2S_3; substance fuses yellow, white amorphous sublimate = Sb_2S_3; reddish-yellow stain = $FeCl_3$; reddish-brown drops, yellow when cold = S; violet vapor, bluish-black sublimate = I. A *gas or vapor* is given off:—The gas is O = nitrates, chlorates, iodates, peroxides, chromium trioxide, and chromates; H_2S = hydrated sulphides, some sulphites; SO_2 = sulphites, hyposulphites, and a few sulphates; NH_3 = ammonium compounds; Oxides of N = nitrates, nitrites; H_2O = hydrates, and crystalline salts. Fumes are given off, also, from iodine, from cyanides, from bromine, and from acetates.

5.—*Heated on charcoal*:—The substance *deflagrates* = nitrates, chlorates, iodates, permanganates, etc. An *incrustation* is formed on the charcoal: Yellow when hot, white when cold = Sn, Zn; yellow both hot and cold = Pb, Bi; reddish-brown = Cd; white = As, Sb.

Preparation of the Solution for Analysis.

6.—If the substance be a metal, dissolve in HNO_3 (Au and Pt are insoluble in HNO_3, soluble in nitro-hydrochloric acid. Sb and Sn may separate as white oxides, filter, wash and dissolve in HCl.) Evaporate the solution to dryness and dissolve the residue in water containing a little HNO_3.

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If the substance be a solid, but not a metal, reduce it to a powder. To a portion add water and boil; (*a*) If all, or part, dissolves, examine the solution obtained for bases. (*b*) To the portion, if any, insoluble in water, add HCl and boil. (*c*) Dissolve any remaining residue in HNO_3, or in nitro-hydrochloric acid. When strong acids are required for the solution, it is best to evaporate the solution to dryness and to redissolve in acidified water before proceeding with the analysis. (*d*) A residue insoluble in acids may be—silica, silicates; sulphate of barium, strontium, or lead; halogen salts of silver; oxides of iron, manganese, aluminum, chromium, and tin, after high heating; carbon, or sulphur. Carbon may be removed by ignition; sulphur, by solution in CS_2. The residue may be fused with Na_2CO_3, or with a mixture of Na_2CO_3 and $NaNO_3$, and the fused mass dissolved in acidified water. Certain of these insoluble substances may be suggested by the results of the preliminary examination, in which case special tests may be used for their identification.

Examination for Metals and Acids.

7.—*For Metals:* Examine for metals according to the Analytical Scheme, page 60. If organic substances be present, ignite the residue, after evaporation of the solution, and dissolve in water acidulated with HCl. Group I. metals will remain undissolved in the hydrochloric acid, and may be tested for in the residue.

8.—*For Acids:* Note that if the substance be soluble in water, acids forming insoluble salts with the metals found can not be present. Refer to the table of solubilities in the Appendix and use the information so obtained in the selection of the tests to follow. The preliminary examination, moreover, may have indicated the possible presence of certain acids, and these may now be tested for directly.

If compounds of the alkalies only are present, proceed at once with the tests given below (*A* to *G*).

If metals other than alkalies are present, add Na_2CO_3 to alkaline reaction, boil, and filter. Divide the filtrate into two unequal parts. To the larger part add HCl until slightly acid, boil thoroughly to remove all CO_2, and test according to *A*, *B*, *C*, *E*, *F* and *G*. To the smaller portion add HNO_3 to acid reaction, boil to expel all CO_2, and test according to *D*.

Arsenic, antimony, lead, mercury, etc., may be removed by

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precipitation with H_2S (after first acidifying, if necessary). Filter, remove excess of H_2S by boiling, and test the solution for acids, or, if other metals are also present, add Na_2CO_3, and proceed as in the last paragraph.

(*A*) Acidify a portion of the solution with HCl. An effervescence = *Carbonates.* (If Na_2CO_3 has been added, to remove the bases, test the original solid or solution for the carbonates.) Divide into three parts. (*a*) Add $BaCl_2$; a precipitate insoluble in hot nitric acid = *Sulphates.* (*b*) Add $FeCl_3$; a dark-blue precipitate = *Ferrocyanides;* a blood-red color destroyed by addition of $HgCl_2$ = *Sulphocyanates;* a blood-red color not destroyed by addition of $HgCl_2$ = *Meconates.* (*c*) Add $FeSO_4$; a dark-blue precipitate = *Ferricyanides.*

(*B*) Acidify a portion of the solution with $HC_2H_3O_2$. Divide into two parts. (*aa*) Add $CaCl_2$; a white precipitate, soluble in HCl = *Oxalates.* (*bb*) Add $NaC_2H_3O_2$ solution and a little neutral $FeCl_3$; a precipitate = *Phosphates.* Note that presence of free mineral acid will prevent this reaction. Phosphates may be tested for, also, by the molybdate test, see page 65.

(*C*) Add $CaCl_2$ (if the solution be acid, first neutralize by addition of dilute NH_4OH, avoiding slightest excess); a precipitate soluble in NaOH, but reprecipitated by boiling = *Tartrates.* If no precipitate forms after shaking and standing, boil the mixture; a precipitate now forming = *Citrates.*

If sulphates be present test for oxalates, tartrates, etc., as follows, using the filtrate from the precipitate obtained by adding $BaCl_2$ in (*A*). Render the filtrate faintly alkaline with NH_4OH and add $CaCl_2$. Let stand for several minutes, filter, and reserve the precipitate. Boil the filtrate; a precipitate soluble in NH_4Cl and reprecipitated by boiling = *Citrates.*

Wash the precipitate reserved above and pour upon the paper acetic acid; an insoluble residue = *Oxalates.* The Acetic acid solution is now tested for *Tartrates,* and for *Phosphates,* by the tests already given.

(*D*) Acidify a portion of the solution with HNO_3 and add $AgNO_3$. If a precipitate form, warm the mixture, filter, and wash. Treat the precipitate on the paper with dilute NH_4OH (1–20). To the solution obtained add HNO_3; a precipitate = chlorides, cyanides (oxalates). Boil with strong HNO_3. If the precipitate be due to *Chlorides* it will remain undissolved, if due to *Cyanides* (or oxalates) it will dissolve. In presence of chlorides, the cyanides may be recognized by their characteristic odor, developed by decomposition of the precipitate with hot dil. H_2SO_4.

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A residue left after the treatment of the first precipitate with dilute NH_4OH may be bromides or iodides. *Bromides* are soluble in *strong* NH_4OH; *Iodides* are insoluble in strong NH_4OH. To further identify these substances, add to the original solution a little starch paste and a few drops of chlorine water; a blue color = *Iodides.* Continue the addition of the chlorine water until the blue color is destroyed, shake with chloroform; the chloroform is colored brownish-yellow = *Bromides.*

(*E*) Apply the $FeSO_4$ test for *Nitrates*, see page 64.

(*F*) To the solution, carefully neutralized if necessary, add neutral $FeCl_3$: A red color easily destroyed by addition of HCl = *Acetates.* (Test for acetates, also, by test 3, page 61.) A red color not destroyed by addition of HCl = *Pyrogallates* (Sulphocyanates, Meconates). Pyrogallates turn black on addition of NaOH and exposure to the air.

A blue-black color on addition of the neutral $FeCl_3$ may be due to *Gallates* or to *Tannates;* the latter precipitate gelatin (best after addition of a little alum), the former do not precipitate gelatin.

A violet coloration may be due to *Phenol* or to phenol derivatives, *Salicylates*, etc. A pinkish precipitate may be due to *Benzoates* or to *Succinates.* Dissolve the precipitate in dilute NH_4OH, concentrate the solution and add HCl; benzoic acid will separate in silky needles.

If to a dilute solution of *Gallic acid* there be added 1 c.c. KCN sol. (1–30), a clear, ruby-red color is obtained, fading on standing, but regenerated by shaking or by adding H_2O_2.

Digallic acid and *Pyrogallol* give a yellowish-red with KCN, and, on adding H_2O_2, digallic acid gives a dirty-white and pyrogallol a yellow-brown.

(*G*) Test for *Borates*, see page 61.

9.—Acids other than those mentioned in the last paragraph may be indicated in the preliminary examination, and may be identified by special tests. *Chromates*, *Manganates*, and *Permanganates* will be suggested by the color of their solutions, by certain of the preliminary tests and by the determination of their metals in the analysis for bases. They may be identified by the tests given on pages 62 and 65.

Hydroxides and *Oxides* will be suggested by negative results with the foregoing tests. The hydroxides and oxides of the metals of

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Groups V. and VI. are nearly all easily soluble in water; other hydroxides and oxides are insoluble in water.

TESTS FOR THE COMMON ALKALOIDS.*

The alkaloids may be described as organic, nitrogenous substances, basic in character, capable of combining directly with acids to form salts. They are commonly divided into two groups: (1) Liquid or Volatile Alkaloids, containing carbon, hydrogen and nitrogen. *Nicotine*, *Sparteine* and *Coniine*. (2) Fixed or Non-Volatile Alkaloids, containing carbon, hydrogen, nitrogen and oxygen. *Morphine*, *Quinine*, *Atropine*, *Strychnine*, etc.

General Properties.—Most alkaloids are insoluble, or very slightly soluble in water; more soluble in alcohol, chloroform and benzene. The salts of the alkaloids, on the other hand, are generally soluble in water and in alcohol, and less soluble in chloroform and benzene. In appearance, they are generally white, with strong taste, and characteristic physiological action. The hydroxides of the alkalies and alkaline earths precipitate alkaloids from aqueous solutions of their salts. Alkali carbonates precipitate most of the alkaloids. Among other precipitants applicable in general to the whole class, we have tannic acid, picric acid, phospho-molybdic acid, solution of iodine in potassium iodide, mercuric potassium iodide (Mayer's solution), and the chlorides of platinum and gold.

Volatile Alkaloids.

These are volatile liquids, colorless when pure and first separated, but turning brown on exposure to the air. They are characterized by disagreeable penetrating odors.

Nicotine, $C_{10}H_{14}N_2$. 1.—Acrid odor and taste (*a rapidly fatal poison*), soluble in ether, chloroform, turpentine, water, and alcohol.

2.—Picric acid, platinum chloride, and mercuric chloride produce precipitates, generally amorphous at first, changing to crystalline. The alkalies, potassium iodide, and potassium chromate, give no precipitates.

* Unless otherwise instructed, the tests for alkaloids should be made upon watch glasses, a minute crystal of the alkaloid being dissolved in as little of the solvent as possible, and the reagent added drop by drop. A soluble salt of the alkaloid may be used, or a solution may be made in water slightly acidulated with sulphuric acid.

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3.—If a drop be placed upon a watch-glass and covered with a second watch-glass carrying a drop of hydrochloric acid, white fumes are produced.

4.—An etherial solution of iodine added to an etherial solution of the alkaloid separates a brownish oil, which gradually becomes crystalline.

5.—With the pure alkaloid, strong hydrochloric acid develops a violet color; nitric acid, an orange-red color; sulphuric acid shows no change.

Coniine, $C_8H_{17}N$. 1.—Resembles nicotine, less soluble in water, freely soluble in ether and chloroform.

2.—Picric acid and mercuric chloride give precipitates. The alkalies, potassium iodide, potassium chromate, and platinum chloride, give no precipitates.

3.—If a drop be placed upon a watch-glass and covered with a second watch-glass carrying a drop of hydrochloric acid, white fumes are produced and the drop of coniine slowly becomes crystalline.

4.—With strong hydrochloric acid, or with nitric acid, a pale red mixture is obtained, the color becoming darker on standing. If the mixture be allowed to evaporate spontaneously, crystals separate. Evaporated with sulphuric acid a red color is developed, changing to green.

Sparteine, $C_{15}H_{26}N_2$. 1.—In general character similar to coniine. The *Sulphate*, U. S. P.$=C_{15}H_{26}N_2.H_2SO_4.5H_2O$. A crystalline powder, odorless, slightly saline, bitter taste, soluble in 1.1 parts water, and in 2.4 parts alcohol.

2.—To the sparteine sulphate in a test-tube add 25 c.c. ether and a few drops of dilute ammonia water, then add etherial solution of iodine (1–50) until the liquid when shaken turns from an orange to a reddish-brown color. After a time the bottom and sides of the tube will show minute dark greenish-brown crystals.

Non-Volatile or Fixed Alkaloids.

By far the greater number of alkaloids belong to this class. They are mostly white, odorless solids, fusing at a temperature above 100° C. without change, but decomposed when heated above their fusing-points.

Aconitine, $C_{34}H_{47}NO_{11}$. 1.—A white powder, soluble in 3200 parts water and in 22 parts alcohol, soluble in ether and in chloroform. A rapidly fatal poison.

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2.—Dilute solutions are precipitated by mercuric potassium iodide, tannic acid, and gold chloride. Strong solutions are precipitated by platinum chloride, mercuric chloride, and by picric acid.

3.—Dissolved in aqueous phosphoric acid and the solution evaporated, a violet color is produced.

4.—With concentrated sulphuric acid a yellowish solution is obtained; with nitric acid, a red-brown solution. The colors obtained, however, vary, and are probably due to impurities.

Atropine, $C_{17}H_{23}NO_3$. 1.—White crystalline powder, soluble in 450 parts water, and in 1.46 parts alcohol, soluble in ether and chloroform. Solutions are alkaline in reaction. *Atropine Sulphate*, $C_{17}H_{23}NO_3.H_2SO_4$. Easily soluble in water, less soluble in alcohol, and much less soluble in chloroform. Solutions are neutral in reaction.

2.—Dilute solutions are precipitated by mercuric potassium iodide, tannic acid, and gold chloride. Strong solutions are precipitated by platinum chloride, mercuric chloride, and picric acid.

3.—Dissolve a fragment of potassium dichromate in sulphuric acid, add a grain of atropine and a few drops of water, and warm the mixture. A pleasing odor resembling that of orange blossoms is developed.

4.—Moisten the alkaloid with strong nitric acid, dry on the water-bath (= colorless residue with odor of hawthorn) cool and add a few drops of alcoholic potassium hydroxide. A violet color is developed, changing slowly to red.

5.—Warmed with sulphuric acid, an odor of hawthorn is developed. There should be no change of color, either with sulphuric, or with nitric acid.

6.—The physiological test, dilatation of the pupil, is characteristic.

Brucine, $C_{23}H_{26}N_2O_4.4H_2O$. 1.—Soluble in alcohol and chloroform, sparingly soluble in water and in ether. The physiological action is similar to that of strychnine, though not so energetic.

2.—Solutions of brucine are precipitated by potassium iodide, potassium chromate, picric acid, platinum chloride, and mercuric chloride.

3.—Chlorine water added slowly to a strong solution of brucine, develops a red color, changing to yellowish-brown by addition of

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ammonia water. With excess of chlorine water a colorless solution is obtained; with small amounts, a red color, changing to violet. With bromine water and brucine sulphate a gray-brown precipitate is obtained, soluble in ammonia water to a greenish solution, fading to a dirty brown.

4.—Treated with strong nitric acid brucine is colored red, turning to a yellow on standing. Addition of stannous chloride changes the red to a violet. (With morphine, stannous chloride gives no change.)

5.—Sulphuric acid gives a colorless solution.

Caffeine (*Theine*), $C_8H_{10}N_4O_2.H_2O$. 1.—Long silky needles, odorless, with bitter taste, soluble in 45.6 parts water, and in 53.2 parts alcohol. Solutions are neutral in reaction.

2. Mercuric chloride gives, slowly, a crystalline precipitate. Potassium iodide, potassium chromate, mercuric potassium iodide, picric acid, and platinum chloride give no precipitates.

3.—Dissolve the alkaloid on a watch-glass in a few drops of concentrated hydrochloric acid, add a minute crystal of potassium chlorate, and evaporate, gently, to dryness. Add a drop of dilute ammonia water, or invert over a second watch-glass containing a few drops of ammonia water. The fine purple color so obtained is destroyed by addition of sodium hydroxide.

4.—Caffeine forms colorless solutions in nitric and sulphuric acids.

Cinchonine, $C_{19}H_{22}N_2O$. 1.—Forms in white crystalline needles almost insoluble in water, slightly soluble in alcohol and chloroform, easily soluble in dilute acids. *Cinchonine sulphate*, $(C_{19}H_{22}N_2O)_2.H_2SO_4.2H_2O$, white, hard, prismatic crystals of bitter taste, soluble in 58 parts water, and in 10 parts alcohol. *Cinchonidine sulphate*, $C_{19}H_{22}N_2O.H_2SO_4.3H_2O$, white glistening needles or prisms, soluble in 63 parts water, and in 72 parts alcohol.

2.—Solutions of cinchonine are precipitated by potassium iodide, potassium chromate, picric acid, platinum chloride, and mercuric chloride.

3.—Potassium ferricyanide gives with cinchonine a precipitate easily soluble in excess; with the sulphate the precipitate does not dissolve but becomes flaky.

4.—Chlorine water and bromine water give yellowish-white precipitates.

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5.—Colorless solutions are obtained with nitric and sulphuric acids—and the solutions show no fluorescence (unlike quinine).

Cocaine, $C_{17}H_{21}NO_4$. 1.—A white crystalline powder, or large, colorless, monoclinic prisms, soluble in 600 parts water, 5 parts alcohol, more soluble in ether and chloroform. Solutions are alkaline in reaction. *Cocaine hydrochloride*, $C_{17}H_{21}NO_4.HCl$, in prisms, leaflets or powder, with saline, slightly bitter taste, soluble in 0.4 part water, and in 2.6 parts alcohol. Cocaine produces a tingling sensation on the tongue, followed by numbness.

2.—The alkaloid is precipitated by picric acid, and by platinum chloride. Potassium iodide and potassium chromate give no precipitates with aqueous solutions of the alkaloid; potassium chromate precipitates cocaine chromate from hydrochloric acid solutions.

3.—Add a few drops of strong hydrochloric acid and then a five per cent. solution of chromium trioxide. An orange crystalline precipitate is obtained on standing. (The precipitate first formed dissolves but reappears.)

4.—Add, drop by drop, a one per cent. solution of potassium permanganate. Small violet-colored crystals are formed.

5.—Solutions in nitric and sulphuric acids should be colorless.

Codeine, $C_{18}H_{21}NO_3.H_2O$. 1.—White, nearly transparent prisms and octahedral crystals, soluble in 88 parts water, and in 1.6 parts alcohol. *Codeine Phosphate*, $C_{18}H_{21}NO_3.H_3PO_4.2H_2O$, soluble in 2.25 parts water, and in 261 parts alcohol. *Codeine Sulphate*, $(C_{18}H_{21}NO_3)_2.H_2SO_4.5H_2O$, soluble in 30 parts water, and in 1035 parts alcohol.

2. The solutions are precipitated by potassium iodide, potassium chromate, picric acid, and platinum chloride. Mercuric chloride gives no precipitate.

3.—With chlorine water a colorless solution is obtained, turning to a red on addition of ammonium hydroxide.

4.—Nitric acid dissolves codeine, giving a yellow solution.

5.—Concentrated sulphuric acid gives a colorless solution which turns blue after several days, or when warmed; best after the addition of a trace of ferric chloride.

Gelsemine, $C_{12}H_{14}NO_2$. (Gerrard.) 1.—A colorless, odorless substance, with bitter taste and alkaline reaction. Very slightly soluble in water, freely soluble in alcohol, chloroform and ether.

2.—The alkaloid is precipitated by potassium dichromate, picric acid, platinum chloride, and mercuric chloride.

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3.—Nitric acid gives a nearly colorless solution, but if this be allowed to evaporate spontaneously a bluish-green stain is left.

4.—Sulphuric acid gives no color with the pure alkaloid. To the sulphuric acid solution add a minute fragment of potassium dichromate. A reddish-purple or cherry-red color appears, and the liquid acquires a greenish-blue or blue color.

Gelsemic Acid. 1.—Colorless, odorless, nearly tasteless, feebly acid substance, nearly insoluble in water, soluble in ether, chloroform, and alcohol. Solubility in water increased by presence of the alkaloid.

2.—With sulphuric acid a faintly yellow solution is obtained. If a drop of ammonium hydroxide be placed in contact with this solution, a copious crystalline deposit will form.

3.—Nitric acid dissolves gelsemic acid to a yellowish-red solution, which turns to a deep red on addition of ammonium hydroxide.

Morphine, $C_{17}H_{19}NO_3.H_2O$. 1.—Rhombic prisms, or fine needles, or as crystalline powder, odorless, with bitter taste, soluble in 3330 parts water, 168 parts alcohol, 4464 parts ether, 1800 parts chloroform, 113.5 parts amyl alcohol, at 25°. Soluble in 1040 parts water at 80° C. *Morphine Acetate*, $C_{17}H_{19}NO_3.C_2H_4O_2.3H_2O$, soluble in 2.25 parts water, and in 21.6 parts alcohol. *Morphine Hydrochloride*, $C_{17}H_{19}NO_3.HCl.3H_2O$, soluble in 17.2 parts water, and in 42 parts alcohol. *Morphine Sulphate*, $C_{17}H_{19}NO_3.H_2SO_4.5H_2O$, soluble in 15.3 parts water, and in 465 parts alcohol.

2.—Morphine is precipitated by iodine in potassium iodide, potassium chromate, picric acid, and platinum chloride. Mercuric chloride gives no precipitate.

3.—Neutral ferric chloride, in neutral solutions, develops a blue color, changing to a green with an excess of the reagent.

4.—Nitric acid produces a deep red color, which gradually fades to a yellow. Addition of stannous chloride does not give a violet color. (Unlike brucine.)

5.—Sulphuric acid forms a colorless solution which is turned slowly to a green on addition of a crystal of potassium dichromate, or to a reddish-pink on addition of a trace of nitric acid. The color with the dichromate is best obtained when strong acid has been used; the color with the nitric acid, best when the sulphuric has been dilute.

6.—On boiling with cupric ammonium sulphate the blue of the reagent is changed to a greenish-blue. (Nadler's reaction.)

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7.—Dissolve the alkaloid in conc. sulphuric acid and add one drop of formaldehyde solution. In the presence of even a trace of morphine, a dark blue-violet color is developed.

Meconic Acid, $C_7H_4O_7.3H_2O$. 1.—Soluble in water, more soluble in alcohol.

2.—To a drop of the solution on a watch-glass add a drop of ferric chloride. A red color appears which is not destroyed by mercuric chloride (differing from ferric sulphocyanate).

3.—Silver nitrate produces a white precipitate which turns red on addition of ferric chloride.

4.—Barium chloride produces a white precipitate.

Quinine, $C_{20}H_{24}N_2O_2.3H_2O$. 1.—A flaky white crystalline powder, odorless, bitter taste, slightly efflorescent in dry air, soluble in 1550 parts water, and in 0.6 part alcohol. *Quinine Hydrobromide*, $C_{20}H_{24}N_2O_2.HBr.H_2O$, soluble in 40 parts water, and in 0.67 part alcohol. *Quinine Hydrochloride*, $C_{20}H_{24}N_2O_2.HCl.H_2O$, soluble in 18 parts water, and in 0.6 part alcohol. *Quinine Salicylate*, $(C_{20}H_{24}N_2O_2)_2.C_7H_6O_3.H_2O$, soluble in 77 parts water, and in 11 parts alcohol. *Quinine Sulphate*, $(C_{20}H_{24}N_2O_2)_2.H_2SO_4.7H_2O$, soluble in 720 parts water, and in 86 parts alcohol. *Quinine Bisulphate*, $C_{20}H_{24}N_2O_2.H_2SO_4.7H_2O$, soluble in 8.5 parts water, and in 18 parts alcohol.

2.—Quinine is precipitated by potassium chromate, picric acid, platinum chloride, and mercuric chloride. Potassium iodide gives no precipitate.

3.—Add to an aqueous solution a few drops of bromine water, or of chlorine water, and then an excess of ammonium hydroxide. A green color is obtained.

4.—To an aqueous solution add chlorine water and a little potassium ferrocyanide. The solution turns pink, then, gradually, red, best after the addition of a few drops of ammonium hydroxide.

5.—Dissolve a few grains of the alkaloid in a little dilute sulphuric acid. A blue fluorescence is obtained. With concentrated nitric acid, a yellowish solution showing a faint bluish fluorescence is obtained.

Strychnine, $C_{21}H_{22}N_2O_2$. 1.—White crystalline powder, with intensely bitter taste (a dangerous poison). Soluble in 6400 parts water, and in 110 parts alcohol. *Strychnine Nitrate*, $C_{21}H_{22}N_2O_2.HNO_3$, soluble in 42 parts water, and in 120 parts alcohol. *Strychnine Sulphate*, $C_{21}H_{22}N_2O_2.H_2SO_4.5H_2O$, soluble in 31 parts water, and in 65 parts alcohol.

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2.—Strychnine is precipitated by potassium iodide, potassium chromate, picric acid, platinum chloride, and mercuric chloride.

8.—Dissolve a minute crystal of strychnine in one or two drops of strong sulphuric acid, and draw through the solution, which should be colorless, a small fragment of potassium dichromate. A blue color is developed, rapidly changing to violet, cherry-red, and finally to yellow. Black oxide of manganese, potassium ferricyanide, or potassium permanganate, may be used in place of the dichromate. The permanganate, however, colors the solution, and thus interferes with the delicacy of the test.

4.—Dissolved in strong nitric acid the solution should be colorless, and on evaporation should yield an odorless yellow residue. (Compare with atropine and brucine.)

5.—Add a drop of nitric acid, warm, and add a small crystal of potassium chlorate. A scarlet coloration is obtained, turning to a brown on addition of ammonium hydroxide.

Veratrine, $C_{32}H_{50}NO_9(?)$. 1.—White, amorphous, occasionally crystalline, powder, bitter taste, soluble in 1750 parts water, and in 2.2 parts alcohol. When heated it melts and gives off acrid fumes.

2.—Amorphous precipitates are obtained with potassium iodide, potassium chromate, picric acid, platinum chloride, and, imperfectly, with mercuric chloride.

3.—Hydrochloric acid dissolves the alkaloid, forming a colorless solution. On warming, a fragrant odor is developed and the solution gradually turns red.

4.—Sulphuric acid dissolves it, giving a solution yellow at first, turning to an orange, and, finally, to carmine-red. The solution shows a partial green fluorescence.

5.—With nitric acid a yellow solution is obtained.

Glucosides, Ptomaines, and Leucomaines.

The Glucosides, substances mostly of vegetable origin, derive their class name from the fact that one of their decomposition products is a glucose or similar body. In their analytical and physiological properties, as well as in their origin, they are not unlike the alkaloids, from which, however, they differ in constitution. As examples we may name: Amygdalin, bryonin, digitalin, helleborin, salicin, etc.

The Ptomaines may be defined as basic compounds formed by

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the action of bacteria on nitrogenous organic matter. Though differing from the alkaloids in origin, they are alkaloidal in nature, and simulate the true alkaloids in their behavior with reagents. They are not to be confused with those other products of bacterial action, the Bacterial Proteids, and the Toxins of disease, nor with the similar Serpent Venoms. As examples of the ptomaines we have: Putrescine, cadaverine, neurine, typhotoxine, mytilotoxine and tyrotoxicon.

The Leucomaines are alkaloidal products of normal body metabolism, and are exampled by adenine, xanthine, hypoxanthine, carnine, spermine and xantho-creatinine.

SEPARATION OF METALS, ALKALOIDS, ETC., FROM ORGANIC MATTER.

The special tests given for the metals and alkaloids are, as a rule, applicable only in absence of organic matter. When, as is often the case, an organ, a tissue, or an organic fluid is presented for examination, it becomes necessary to either remove or destroy the organic matter before proceeding with the analysis. Many processes have been proposed, but all, though simple in theory, require expert chemical knowledge for their successful application. The methods given below for metals are particularly adapted to the separation of arsenic, but apply with slight modifications to all of the metallic poisons.

Separation of Metals. *Method of Fresenius and Babo.*—The solid matter is finely divided and treated with an equal weight of a mixture of pure hydrochloric acid (1 part) and water (3–4 parts). The mixture is then digested on a water-bath and small quantities of potassium chlorate added from time to time. When the solid matter has been entirely decomposed the clear yellow liquid is evaporated, until the odor of chlorine has disappeared, or the chlorine is removed by passing carbon dioxide gas through the solution. The solution is now filtered and examined, by the usual tests, for the metals; in the case of *arsenic*, best after reduction by sulphur dioxide and subsequent warming to remove the excess of the gas.

By Distillation.—In the case of arsenic, and of certain volatile compounds of metallic poisons, the following method may be used: The finely divided organic matter is dried on the water-bath, mixed with its own weight of pure hydrochloric acid and

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distilled from a glass retort provided with a condenser. The distillate is received in cold water, and may be examined at once for poisons.

By Dialysis.—The finely-cut material is digested in cold water—or in dilute acid—for 24 hours, and then placed in a dialyzer. The latter is suspended in a larger vessel containing distilled water, and at the end of another 24 hours the water is evaporated and the residue examined for poisons. This method is applicable, also, to the separation of the alkaloids.

SEPARATION OF ALKALOIDS, GLUCOSIDES, ETC., FROM ORGANIC MATTER. The separation of the alkaloids from organic matter is one of the most difficult, and on the whole, one of the most unsatisfactory problems of chemical toxicology. The following outlines will indicate the general nature of the processes used:

Stas-Otto Method.—Treat the finely comminuted mass with twice its weight of pure 90 per cent. alcohol, and with 10 to 30 grains of oxalic acid. Digest at 70° C., and filter. Evaporate the filtrate in vacuo, over sulphuric acid, dissolve the residue in absolute alcohol, filter, and again evaporate at a low temperature. Dissolve in water and extract with ether until all coloring matter is removed, then add sodium carbonate to alkaline reaction, again agitate with ether, and separate the ethereal layer. Allow the ether to evaporate spontaneously and examine the residue for alkaloids. With the coloring matter the first ethereal extract may contain colchicine, digitalin and picrotoxin. Most of the alkaloids will pass into the second extract, that from the alkaline solution; morphine, however, being nearly insoluble in ether, will remain, and should be examined for by extraction of the alkaline solution with amyl alcohol.

Dragendorff's Method.—This method is convenient, as affording a partial separation of the alkaloids during their extraction. The finely divided substance is digested for several hours with water acidulated with sulphuric acid. The extract is removed and the process repeated, the temperature being maintained at from 40° C. to 50° C. The extracts are united, evaporated to a syrup, and digested with four volumes of alcohol for 24 hours at 30° C. The alcoholic extract is filtered, the residue washed with 70 per cent. alcohol, and the united extracts freed from alcohol by evaporation. The aqueous residue, diluted if necessary, is filtered, and the acid liquid, containing the sulphates of the alkaloids, treated with the following reagents:

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1.—Agitate with petroleum ether, remove ethereal layer, repeat extraction, evaporate extracts. Residue consists chiefly of *coloring matters*, but may contain, also, *piperine*, *picric acid*, *camphor*, *phenol*, etc.

2.—Extract with benzene. Evaporate extract. Residue, if crystalline, may be *cantharidin*, *santonin*, or *digitalin*, *caffeine*, *piperine*, or *berberine;* if amorphous, *elaterin*, *populin*, *colocynthin*, or *colchicine*.

3.—Extract with chloroform. Evaporate extract. Residue may be *digitalin*, *picrotoxin*, *helleborin*, *saponin*, *cinchonine*, or *theobromine*.

4.—Treat again with petroleum ether, remove etherial layer, render alkaline with ammonia. Treat the alkaline solution with petroleum ether, remove and evaporate the extract. Residue may be *strychnine*, *quinine*, *brucine*, *veratrine*, *coniine*, *nicotine*, *sparteine*, or *aniline*.

5.—Extract the alkaline solution with benzene. Evaporate extract. Residue may be *strychnine*, *brucine*, *quinine*, *cinchonine*, *atropine*, *hyoscyamine*, *physostigmine*, *aconitine*, *codeine*, *thebaine*, *narceine*, *narcotine*, or *veratrine*.

6.—Extract with chloroform. Evaporate extract. Residue may be *morphine*, *cinchonine*, *papaverine*, or *narceine*.

7.—Extract with amyl alcohol. Evaporate extract. Residue may be *morphine*, *solanine*, or *salicin*.

8.—Evaporate remainder of the solution with powdered glass. Extract with chloroform. Evaporate extract. Residue may be *curarine*.

General Plan of Analysis for Common Poisons.

I. If strongly acid, test for *Sulphuric acid*, *Nitric acid*, *Oxalic acid*, etc.

II. Acidify a portion with hydrochloric acid, filter if necessary, and apply the Reinsch test for *Arsenic*, *Antimony* and *Mercury*.

III. Dry a portion and burn to an ash. Dissolve this in hot hydrochloric acid and test for *Lead*, *Copper* and *Zinc*.

IV. If the original, alone or after adding sulphuric acid, gives odor of *Hydrocyanic acid*, or *Phenol*, apply special tests for these substances.

V. Apply Stas-Otto method for *Alkaloids*. For the preliminary

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tests this may be modified as follows: Evaporate gently, if necessary, to dryness on the water-bath. Add strong alcohol and a small crystal of tartaric acid. Digest and filter. Evaporate and take up in warm water made slightly acid with acetic acid. Cool and filter. Extract with ether, which dissolves here the coloring matter and some glucosides. Make alkaline with sodium bicarbonate, extract with chloroform, which dissolves all the common alkaloids but morphine. Extract with amyl alcohol and examine this extract for morphine.

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QUANTITATIVE ANALYSIS.

Quantitative Analysis is that branch of chemistry which treats of the methods used for accurately determining the amounts of elements or compounds. This may be accomplished by either *gravimetric* or *volumetric* processes. In the former, the constituents are precipitated from solution by reagents, the precipitates are dried and weighed, and from their weights the composition of the substance is calculated.

Thus, *gravimetrically*, the per cent. of iron in iron ore can be determined by dissolving a weighed amount of the ore in hydrochloric acid, adding water and then an excess of ammonium hydroxide, which will precipitate all the iron as ferric hydroxide. This precipitate may be collected on a filter paper, washed with water until free from impurities, dried and weighed; or the precipitated ferric hydroxide may be heated and the computations, based upon the weight of ferric oxide formed, made as follows:

Molecular weight of the ferric oxide : atomic weight of iron :: weight of ferric oxide found : weight of iron in the sample (x).

Volumetric analyses are, as a rule, more quickly performed and require less extensive laboratory appliances, hence are used almost entirely in clinical diagnosis. They are based upon the use of standard solutions which contain definite and known amounts of chemicals suited for the particular purpose for which they are to be used. Solutions called normal solutions are in common use, although often the strength is adjusted so that each cubic centimeter will represent a convenient amount of the substance to be determined.

Acid solutions are said to be *Normal* ($\frac{N}{1}$) when they are of such strength that one gramme of replaceable hydrogen of the acid is contained in each 1000 cubic centimeters.

36.18 grammes of hydrochloric acid contain one gramme of replaceable hydrogen, hence by definition, 1000 c.c. of a normal solution of hydrochloric acid will contain 36.18 grammes of that acid.

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97.37 grammes of sulphuric acid contain two grammes of replaceable hydrogen; hence, if 48.675 grammes of sulphuric acid be contained in 1000 cubic centimeters, it will be a normal solution.

A normal solution of a base is one of such strength that 1000 cubic centimeters of it will exactly neutralize 1000 cubic centimeters of a normal acid. From the chemical equation $HCl + NaOH = NaCl + H_2O$ we see that 36.18 grammes of hydrochloric acid is neutralized by 39.76 grammes of sodium hydroxide. Hence a solution of sodium hydroxide containing 39.76 grammes in 1000 c.c. will be a normal solution.

In a like manner it may be shown that 1000 c. c. of a normal solution of potassium hydroxide contains 55.74 grammes.

With a careful study of the above specifications and a knowledge of chemical equations it can be seen that

Each Cubic Centimeter of a Normal Acid Solution will exactly neutralize:

	Grammes.
Ammonia, NH_3	0.01693
Ammonium hydroxide, NH_4OH	0.03481
Lithium carbonate, Li_2CO_3	0.03675
Potassium bicarbonate, $KHCO_3$	0.09941
Potassium carbonate, K_2CO_3	0.06863
Potassium hydroxide, KOH	0.05574
Sodium bicarbonate, $NaHCO_3$	0.08343
Sodium carbonate, Na_2CO_3	0.05265
Sodium hydroxide, NaOH	0.03976

and that

Each Cubic Centimeter of a Normal Alkali Solution will exactly neutralize:

	Grammes.
Acid, Acetic, $HC_2H_3O_2$	0.05958
Boric, H_3BO_3	0.06154
Citric, $H_3C_6H_5O_7.H_2O$	0.06950
Hydrobromic, HBr	0.08036
Hydrochloric, HCl	0.03618
Hydriodic, HI	0.12690
Lactic, $HC_3H_5O_3$	0.08937
Nitric. HNO_3	0.06257
Oxalic, $H_2C_2O_4.2H_2O$	0.06255
Sulphuric, H_2SO_4	0.04867
Tartaric, $H_2C_4H_4O_6$	0.07446

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Since each cubic centimeter of a normal acid or alkali solution neutralizes a definite amount of alkali or acid respectively, the strength of an acid or alkali can be accurately determined by adding the appropriate normal solution until the neutralization point or end reaction is reached. This operation is called *titration.*

Indicators.—The success of the volumetric process depends upon the accuracy with which we determine the completion of the chemical reaction between the reagent and the substance under titration, that is the neutralization point or end reaction. This is generally accomplished by adding to the solution a substance which will reveal by change of color the slightest excess of the reagent. The substance so used is known as an indicator, and must answer to the following conditions: The completion of the test, or end reaction, must be marked by an indisputable change in color; but little of the indicator should be used, and the color change must not be interfered with by any impurities present, nor by the products of the reaction itself. The following are some of the indicators in common use. For their preparation, see Appendix.

Litmus.—Red with acids, blue with alkalies. Litmus is used chiefly in the titration of the mineral acids and alkalies; it is not reliable as an indicator in presence of carbonates, phosphates or arsenates.

Phenolphthalein.—Colorless with acids, magenta-red with alkalies. This indicator is much used and is extremely delicate, but its value is lessened by presence of ammonium salts or of borax.

When it is necessary to use phenolphthalein or litmus in presence of carbonic acid (carbonates), the solution under titration should be boiled.

Methyl Orange.—Red with acids, yellow with alkalies. It is not affected by carbonic anhydride, and hence may be used in presence of carbonates, but it is not satisfactory with organic acids.

Cochineal.—Yellow with acids, violet with alkalies. Used chiefly with ammonia and ammonium compounds.

A long graduated tube having a stop cock or some other device at the lower end for opening and closing, is used for measuring volumetric solutions. Such an instrument is called a *burette.*

Method of Analysis.—A weighed quantity of the acid or alkali is diluted with a little water, a few drops of the indicator added, and then the standard alkali or acid, from a burette, until a change of tint is developed. The number of c.c. of standard solution

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used, multiplied by the equivalent of each c.c. gives the weight of pure acid or alkali in the solution. From this, and the weight of the sample, the percentage may be calculated.

Example. If 5 grammes of hydrochloric acid solution were taken for analysis, and 20 c.c. of normal alkali were required to develop the pink color with phenolphthalein, then the 5 grammes of acid solution contain, $20 \times 0.03618 = 0.7236$ gramme of pure acid, or, $0.7236 \div 5 \times 100 = 14.47$ per cent.

Remarks.—It is often inconvenient to weigh the sample taken for analysis, and in such a case, a definite *volume* must be used. The titration with the normal solution will give the number of grammes of pure substance in the sample. In the titration of carbonates, methyl orange is to be used as the indicator, the standard acid being added until the solution acquires a faint orange-red tint.

Normal solutions of salts are also sometimes used for special purposes. They are made of such strength that they contain the molecular weight of the salt expressed in grammes dissolved in 1000 cubic centimeters, if the acid from which the salt is formed is a monobasic acid, and if dibasic, only one-half this amount.

Thus the molecular weight of silver nitrate is 168.69, and as nitric acid is a monobasic acid a normal solution of silver nitrate will contain 168.69 grammes in 1000 cubic centimeters.

Normal ($\frac{N}{1}$) solutions are not the only standard solutions in use. Often it is more convenient to use solutions one-tenth as strong or deci-normal ($\frac{N}{10}$), or one-twentieth ($\frac{N}{20}$), or centi-normal ($\frac{N}{100}$), or half normal ($\frac{N}{2}$), or double normal ($\frac{2}{N}$). Corresponding corrections, of course, must be made in computation.

Sometimes it is advisable to make volumetric solutions so that each cubic centimeter represents a convenient amount of the substances to be estimated. See under Dextrose.

It is not always practical to prepare volumetric solutions precisely of the desired strength, but a "*correction*" may easily be computed for each solution. The "*correction*" when multiplied by the number of cubic centimeters of the particular solution used will give the equivalent number of cubic centimeters of standard solution.

For example:—If 25 c.c. of a solution of sodium hydroxide is required to exactly neutralize 20 c.c. of a normal solution of sulphuric acid, it can be seen that the sodium hydroxide solution is

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weaker than a normal solution. A number can easily be found, which when multiplied by 25 will give 20 ($20 \div 25 = 0.8$). This number, 0.8, is known as the "*correction*," and is always to be multiplied by the number of cubic centimeters used of this solution before further computation is made.

Estimation of Haloid Salts.

Salts of chlorine, bromine and iodine, may be conveniently estimated by precipitation with a standard solution of silver nitrate. The reagent is added until all of the halogen has been precipitated as silver salt, and from the number of c.c. used the original halogen compound may be calculated. The completion of the reaction may be determined by testing small portions of the solution from time to time, filtering off the precipitate and adding a drop of silver nitrate, until no further precipitation occurs. Much more satisfactorily, however, we can add to the solution a few drops of potassium chromate, which, by formation of red silver chromate when all of the halogen has been precipitated, will reveal the slightest excess of the silver nitrate.

Deci-Normal Silver Nitrate.—Dissolve 16.869 grammes of pure silver nitrate in water and dilute to 1 litre, at 25° C. (The molecular weight of silver nitrate being 168.69, the deci-normal solution will contain $\frac{1}{10}$th of the molecular weight, expressed in grammes.) The solution should be kept in the dark.

Each Cubic Centimeter of Deci-Normal Silver Nitrate Solution is equivalent to:

	Grammes.
Ammonium Bromide, NH_4Br . .	0.009729
Chlorine, Cl	0.003518
Lithium Bromide, LiBr . . .	0.008634
Potassium Bromide, KBr . . .	0.011822
Potassium Chloride, KCl . . .	0.007404
Potassium Cyanide, KCN . . .	0.012940
Potassium Iodide, KI . . .	0.016476
Sodium Bromide, NaBr . . .	0.010224
Sodium Chloride, NaCl . . .	0.005806
Zinc Chloride, $ZnCl_2$	0.006763

Method of Analysis.—To a measured volume of the salt solution, or to a weighed quantity of the salt dissolved in water, add a few

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drops of potassium chromate, and then the deci-normal silver nitrate, from a burette, until the solution acquires a slight but permanent red tinge. The number of c.c. of the deci-normal solution used, multiplied by the equivalent of each c.c., gives the weight of the halogen salt in solution. From this and the weight of the sample, the percentage strength can be calculated.

In titrating potassium cyanide, no indicator is used, but the silver nitrate is added until the appearance of the first, slight, permanent precipitate.

Special Volumetric Processes, applicable in urine analysis, in the analysis of the gastric fluid, water, etc., are described in the clinical section of this book.

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PART II.

CHEMISTRY

OF THE

CARBON COMPOUNDS.

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CHEMISTRY OF THE CARBON COMPOUNDS.

Chemistry is customarily divided into two portions, Organic and Inorganic.

This general division has long been adopted, and originally was intended to differentiate between compounds associated with life and those relating to the inanimate. At present, however, by Organic Chemistry is understood the Chemistry of the Carbon Compounds, though the carbonates are classified as inorganic.

The carbon atom possesses the peculiar property of being able to join directly with other carbon atoms, thus making possible innumerable combinations.

HYDROCARBONS are the simplest organic compounds, being composed of only hydrogen and carbon.

Several series of hydrocarbons are known. The two most important are the Methane or Marsh gas series, having a general formula of C_nH_{2n+2}, and the Benzene or Aromatic series, having a general formula C_nH_{2n-6}. A few members of the Ethylene series, C_nH_{2n}, and the Acetylene series, C_nH_{2n-2} are also important.

DERIVATIVES OF THE HYDROCARBONS.

There are many derivatives of hydrocarbons formed by replacing one or more of the hydrogen atoms with other elements or groups of elements, the compounds being classified according to the kind of element or group substituted:

HYDROCARBON RADICALS are those derived from the hydrocarbon by replacing part of its hydrogen. They usually take their name from the name of the hydrocarbon; thus from Methane (CH_4), Ethane (C_2H_6), Propane (C_3H_8), Butane (C_4H_{10}), and Pentane (C_5H_{12}), by dropping one atom of hydrogen we have the monatomic radicals, Methyl (CH_3), Ethyl (C_2H_5), Propyl (C_3H_7), Butyl (C_4H_9) and Pentyl, also called Amyl, (C_5H_{11}).

AN ALCOHOL is formed from the hydrocarbon by substituting

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one or more hydroxyl (OH) groups for one or more hydrogen atoms. According to the number of hydroxyl groups present, alcohols are classed as monatomic, diatomic, triatomic, etc. Depending upon the arrangement of the atoms in the molecule, we have the isomeric primary, secondary, and tertiary alcohols. Primary alcohols on oxidation yield aldehydes and acids, secondary alcohols yield ketones or acetones, tertiary alcohols undergo decomposition.

AN ALDEHYDE contains the group (—COH).

A KETONE contains the group (=CO).

AN ORGANIC ACID is formed from the hydrocarbon by substituting one or more carboxyl groups (—COOH) for one or more hydrogen atoms.

AN ETHER is formed by substituting an atom of oxygen for two atoms of hydrogen. Two molecules of the hydrocarbon are required and one hydrogen atom from each is replaced.

AN ESTER, COMPOUND ETHER or ETHERIAL SALT is derived from the hydrocarbon by replacing part of its hydrogen with an acid radical.

NITRO COMPOUNDS contain the group (NO_2).

CYANOGEN COMPOUNDS contain the (CN) radical, which occurs in several forms: (*a*) In cyanides (–C≡N), (*b*) isocyanides (–N≡C), (*c*) cyanates (–C≡N=O), (*d*) isocyanates (–N=C=O), (*e*) sulphocyanates (–S–C≡N), and (*f*) isosulphocyanates (–N=C=S).

AMINES. These may be regarded as formed from ammonia, NH_3, by substituting hydrocarbon radicals for one or more of the hydrogen atoms. *E. g.*, METHYLAMINE, $NH_2(CH_3)$. DIMETHYLAMINE, $NH(CH_3)_2$. TRIMETHYLAMINE, $N(CH_3)_3$. Some of the alkaloids and many of the ptomaines belong to this class.

AMIDO, OR AMINO, ACIDS. These important compounds may be regarded as formed from the acids by substituting Amidogen, NH_2, for the hydrogen of the hydrocarbon radical. *E. g.*, from acetic acid, CH_3COOH, we have AMIDOACETIC ACID, $CH_2(NH_2)COOH$, known also as Glycocol or Glycocin, an important constituent of the animal body.

Other Amido Acids of the animal body are LEUCIN, TYROSIN, CHOLIN, TAURIN and CYSTIN.

AMIDES. These may be regarded as formed from the acids by substituting amidogen, NH_2, for the (OH) of the carboxyl group. *E. g.*, Acetic Acid, CH_3COOH, ACETAMIDE, $CH_3CO(NH_2)$.

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UREA, $CO(NH_2)_2$, (Carbamide), may be regarded, theoretically, as the amide of carbonic acid, $CO(OH)_2$, two groups of (NH_2) taking the place of the two (OH) groups. Urea is the chief nitrogenous constituent of the urine in mammals. It is a crystalline substance easily soluble in water, less soluble in alcohol, insoluble in ether.

MERCAPTANS, alcohols in which oxygen has been replaced by sulphur. *E. g.*, Ethyl mercaptan, C_2H_5SH.

SULPHONIC ACIDS, formed by substituting a hydrocarbon radical for an (OH) group in sulphuric acid. *E. g.*, Ethyl sulphonic acid, $C_2H_5HSO_3$. (Compare with ethyl sulphuric acid, $C_2H_5HSO_4$.)

THIO ETHERS, *e. g.*, Ethyl thioether, $(C_2H_5)S$.

AZO COMPOUNDS, DIAZO COMPOUNDS and HYDRAZINES are all characterized by the group N_2. They differ from each other in the constitution of the N_2 group. In the azo compounds this group has the arrangement —N=N—, in the diazo N≡N- and in the hydrazins the N_2 group is combined also with two atoms of hydrogen —HN=NH—.

Azo compounds are formed by the reduction of the nitro compounds in alkaline solution; if the reduction takes place in acid solution amido compounds are formed.

METHANE OR MARSH GAS SERIES AND DERIVATIVES.

The members of this series of hydrocarbons are "saturated"—that is, they contain the greatest possible number of hydrogen atoms for the number of carbon atoms present.

The first member, Methane (CH_4), a gas commonly called Marsh Gas or "Fire Damp," is an important constituent of illuminating gas and one of the products formed when vegetable matter decays under water.

The second member, Ethane, C_2H_6, is also a gas and is present in illuminating gas.

Propane, C_3H_8, Butane, C_4H_{10}, Pentane, C_5H_{12}, and Hexane, C_6H_{14}, follow in order named.

The members before Butane are gases, those next after, liquids, and the very high members, the paraffins, are solids at ordinary temperatures.

Structural formulas may be written for any of these hydrocarbons, and by adding a CH_2 group to the preceding formula the next member is obtained. Thus:—

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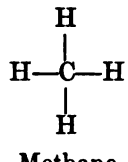
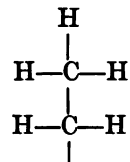
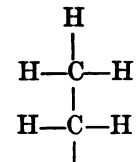


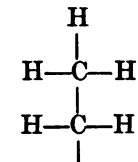
Methane, CH_4.



Ethane, C_2H_6.



Propane, C_3H_8.



Butane, C_4H_{10}.

By the FRACTIONAL DISTILLATION OF CRUDE PETROLEUM the hydrocarbons of this series are separated into groups and used commercially under various names. These, with their boiling points, are as follows:

Cymogene or *Petroleum Ether No. I.*, 0° C.; *Rhigolene* or *Petroleum Ether No. II.*, 20° C.; *Common Petroleum Ether*, 40°–70° C., including *Gasolene*, 48° C., and *Benzin*, U. S. P. 45°–60° C.; *Naphthas, C, B, and A*, 80°–150° C.; *Kerosene*, 150°–220° C.; *Lubricating oils*, 300° C.; and, finally, the solid *Paraffins*, melting point 40°–55° C., and the residue Ceresin, melting point, 55°–65° C.

Petroleum ether consists largely of pentane, C_5H_{12}.

PETROLEUM BENZIN or BENZINE consists chiefly of C_5H_{12} and C_6H_{14}.

BENZINUM PURIFICATUM, U. S. P., is prepared by treating the benzin with sulphuric acid and potassium permanganate, and after twenty-four hours, with sodium hydrate and potassium permanganate, and then washing with water.

KEROSENE, COAL-OIL or ILLUMINATING OIL is prepared by distilling crude petroleum, and is the fraction between 150°–220° C. The distillate is "refined" by treatment with sulphuric acid, then neutralized with sodium hydrate and redistilled.

PETROLATUM LIQUIDUM, U. S. P., is a transparent, odorless, oily liquid obtained by distilling the more volatile portions from petroleum and purifying. Its specific gravity is from 0.870 to 0.940 at 25° C.

Albolene and liquid vaseline are trade names for similar liquids.

The official PETROLATUM and PETROLATUM ALBUM are more solid, of about the consistence of an ointment.

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Alcohols.

Methyl Alcohol, CH_3OH. (Wood Alcohol.) A product obtained in the destructive distillation of wood. A colorless liquid with spirituous odor, boiling at 66° C., lighter than water, mixes with water, burns with a pale bluish flame and is poisonous.

Test for methyl alcohol.—Oxidize a spiral of clean copper wire by heating to a dull red. Place the liquid, which should be diluted below the point where it will burn, in a long test-tube, and plunge the heated spiral wire to bottom of the tube. Repeat several times. In presence of methyl alcohol the black oxide of copper is removed and formaldehyde is produced.

If the formaldehyde cannot be identified by odor, filter the solution, add 5 drops of resorcinol solution (1–200), incline test-tube and pour a layer of concentrated sulphuric acid under the solution; a pink ring at point of contact will indicate formaldehyde.

Ethyl Alcohol, C_2H_5OH. Prepared by fermentation of glucose, the latter having been made by the action of a diastatic ferment on starch. A colorless liquid with spirituous odor and sharp burning taste. Mixes in all proportions with water, ether, or chloroform. Burns with a pale bluish flame. Boils at 78° C. *Alcohol*, U. S. P., 92.3 per cent. by weight, 94.9 per cent. by volume. Sp. gr., 0.816 at 15.6° C. (60° F.), 0.809 at 25° C. (77° F.).

Dilute Alcohol, U. S. P. 41.5 per cent. by weight, 48.9 per cent. by volume, made by mixing equal volumes of water and alcohol. Sp. gr. about 0.936 at 15.6° C., or 0.930 at 25° C.

Absolute Alcohol, U. S. P. Contains not more than one per cent., by weight, of water. Sp. gr., 0.797 at 15.6° C., 0.790 at 25° C.

Tests for Alcohol. 1.—To a dilute solution of potassium dichromate add a few drops of strong sulphuric acid, and then a little alcohol, or the solution to be tested. Warm the mixture: it turns green, and the characteristic odor of aldehyde, CH_3COH, is produced.

$$K_2Cr_2O_7 + 4H_2SO_4 + 3C_2H_5OH = Cr_2(SO_4)_3 + 3CH_3COH + K_2SO_4 + 7H_2O.$$

2.—To 10 c.c. of the liquid to be tested add five drops of 10 per cent. sodium hydroxide, warm to about 50° C., then add a solution of iodine in potassium iodide until the liquid is faintly colored. A precipitate of iodoform will be produced. Note the characteristic odor.

$$C_2H_5OH + 6KOH + 4I_2 = CHI_3 + CHO_2K + 5KI + 5H_2O.$$

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An excess of alcohol holds the iodoform in solution.

3.—To 5 c.c. of solution to be tested add a few drops of a strong solution of sodium acetate, then 5 c.c. of concentrated sulphuric acid. The characteristic fruit-like odor of ethyl acetate will be developed on warming.

$$C_2H_5OH + NaC_2H_3O_2 + H_2SO_4 = C_2H_5C_2H_3O_2 + NaHSO_4 + H_2O.$$

Tests for Purity of Alcohol.—It should boil at 78° C. It should not affect the color of litmus paper. Fifty c.c. on evaporation should leave no color and no weighable residue, and should have no foreign odor. Mixed with one-half its volume of potassium hydroxide, the liquid should not at once become dark-colored (aldehyde, methyl alcohol, oak tannin). When shaken with one-twentieth its volume of silver nitrate solution, the mixture should not become more than faintly opalescent, and, on exposure to diffused daylight for six hours, should not acquire more than a faint brownish tint (organic impurities, amyl alcohol, aldehyde).

To test for "fusel oil" in alcohol, dilute the latter to a strength of about 12 per cent., shake with chloroform, separate and evaporate the chloroform extract. On warming the residue with potassium acetate and a few drops of sulphuric acid, the characteristic odor of amyl acetate will be developed.

AMYL ALCOHOL, $C_5H_{11}OH$. A colorless, oily liquid, boils at 131° C., soluble in 40 parts water, mixes in all proportions with alcohol, ether, etc.

Fusel oil contains amyl alcohol with varying amounts of propyl and butyl alcohols. For tests see under ethyl alcohol.

GLYCOL, $C_2H_2(OH)_2$. A diatomic alcohol.

GLYCERIN, $C_3H_5(OH)_3$. (Glycerol.) A triatomic alcohol from propane. Made by the decomposition of fat by an alkali (saponification) or by superheated steam.

$$\underset{\text{Olein}}{C_3H_5(C_{18}H_{33}O_2)_3} + 3KOH = \underset{\text{Potassium oleate}}{3KH_{18}H_{33}O_2} + \underset{\text{Glycerin}}{C_3H_5(OH)_3}$$

$$\underset{\text{Olein}}{C_3H_5(C_{18}H_{33}O_2)_3} + 3H_2O = \underset{\text{Oleic acid}}{3HC_{18}H_{33}O_2} + \underset{\text{Glycerin}}{C_3H_5(OH)_3}$$

It is an odorless, colorless, syrupy liquid with slight sweetish taste producing a sense of warmth in the mouth. Specific gravity not less than 1.246 at 25° C. Mixes with water and with alcohol but not with ether, chloroform or the oils. Absorbs moisture on exposure to the air.

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Tests for glycerin. 1.—Add sodium hydroxide to a slightly alkaline reaction, and heat, in a non-luminous flame, a borax bead moistened with this solution. Boric acid is produced and the flame is colored green.

2.—Boil with sulphuric acid. The characteristic odor of acrolein, C_3H_4O, is produced.

3.—To detect glycerol in a saccharine liquid mix the latter with $Ca(OH)_2$ and sand, and evaporate on a water-bath. Extract the nearly dry residue with alcoholic ether and evaporate the extract. Test the residue with the borax bead, as in test 1.

Tests for purity of glycerin.—For medicinal use, the aqueous solution of glycerol should be neutral to litmus paper; no brown color should develop when it is treated with sulphuric acid, and no red precipitate should be obtained on heating with Fehling's solution. With Trommer's test a blue solution is obtained, but no precipitate.

GLYCEROPHOSPHORIC ACID, $C_3H_5(OH)_2H_2PO_4$, and GLYCERYL TRINITRATE, $C_3H_5(NO_3)_3$ (Nitroglycerin), are important derivatives of glycerin.

MANNITE or MANNITOL, $C_6H_8(OH)_6$. Hexatomic alcohol, from which may be derived certain of the carbohydrates.

ALDEHYDES. (METHANE SERIES.)

Aldehydes are made by the oxidation of primary alcohols. They are characterized by the monatomic group—COH.

FORMALDEHYDE, HCOH. Made by oxidizing methyl alcohol. A gas, soluble in water, the official solution containing not less than 37 per cent. by weight, making a colorless liquid with pungent odor and caustic taste. The 40 per cent. aqueous solution of formaldehyde is known as *Formalin.*

Tests for formaldehyde. 1.—Silver ammonium nitrate added to a dilute solution produces a gray precipitate of metallic silver, sometimes obtained as a mirror on the inside of the tube.

2.—To 5 c.c. sulphuric acid with a little salicylic acid dissolved, add 2 drops of formaldehyde and warm gently. A permanent red color appears.

3.—To 1 c.c. of the liquid add 2 drops of a solution consisting of 1 gramme of phenylhydrazin hydrochloride with 1.5 grammes of sodium acetate in 10 c.c. of water, then add 2 drops of sulphuric acid. A green color is developed (in dilute solutions slowly, and best after warming).

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For other tests, see under Milk Analysis.

ACETALDEHYDE, CH_3COH. (Aldehyde.) A volatile, colorless liquid.

CHLORAL, CCl_3COH. (Trichloraldehyde.) An oily liquid made by the action of chlorine on acetaldehyde or on absolute alcohol. Soluble in water.

$$C_2H_5OH + Cl_2 = \underset{\text{acetaldehyde}}{CH_3COH} + 2HCl$$

$$CH_3COH + 3Cl_2 = CCl_3COH + 3HCl$$

HYDRATED CHLORAL, U. S. P., $CCl_3COH.H_2O$. Transparent crystals with penetrating, pungent odor, and bitter caustic taste. Soluble in water, alcohol, ether and chloroform. Liquefies when triturated with an equal quantity of camphor, menthol, or thymol.

Tests for chloral. 1.—Add a solution of sodium hydroxide and warm; the chloral is decomposed with the formation of chloroform and sodium formate. Note the odor.

2.—Add the chloral to dilute silver ammonium nitrate and warm *gently;* a silver mirror is formed on the tube. This reaction is characteristic of all aldehydes.

3.—Add acetic acid and then ammonium sulphide to a dilute aqueous solution of chloral. A brownish-red color, or precipitate, and a penetrating odor will develop.

4.—Chloral may be extracted from an aqueous solution by agitation with ether. Note, also, that chloral will respond to the first test given for chloroform.

ACETONES OR KETONES.

These compounds are formed by the oxidation of secondary alcohols; and are characterized by the diatomic group, carbonyl, CO.

ACETONE, $(CH_3)_2CO$. (Dimethylketone.) A colorless, volatile liquid, with etherial odor. Mixes with water and with alcohol, etc. Used as a solvent. For tests, see under Urine Analysis.

ACIDS. (METHANE SERIES.)

Formed by the oxidation of aldehydes, or by the complete oxidation of the primary alcohols. Characterized by the monatomic group, carboxyl, COOH. According to the number of carboxyl groups present an acid is monobasic, dibasic, tribasic, etc.

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Monobasic Acids.

Formic Acid, HCOOH. A colorless liquid with penetrating odor. Applied to the skin it produces blisters.

Acetic Acid, CH_3COOH. A product obtained in the destructive distillation of wood and made, also, by the oxidation of alcohol through the agency of the *mycoderma aceti.* A clear colorless liquid with characteristic odor. See List of Reagents in the Appendix, and, for tests, see page 61. *Glacial Acetic Acid*, U. S. P., is a clear colorless liquid containing not less than 90 per cent. of the acid. Solidifies at a little below 15° C. *Acetic Acid*, U. S. P., contains 36 per cent. of the acid. *Diluted Acetic Acid*, U. S. P., contains 6 per cent. of the acid.

Mono- Di- and Tri-chloracetic acids are made by substituting one, two, or three atoms of chlorine for one, two, or three atoms of hydrogen. Tri-chloracetic Acid, CCl_3COOH, white deliquescent crystals with pungent odor, very soluble in water, alcohol, and ether. The aqueous solution on boiling decomposes into chloroform and carbon dioxide.

Butyric Acid, C_3H_7COOH, Caproic Acid, $C_5H_{11}COOH$, Palmitic Acid, $C_{15}H_{31}COOH$, and Stearic Acid, $C_{17}H_{35}COOH$, are found combined with the triatomic radical, Glyceryl, C_3H_5, in fats and fixed oils. Other less important acids are Caprylic, $C_7H_{15}COOH$, Capric, $C_9H_{19}COOH$, Lauric, $C_{11}H_{23}COOH$, and Myristic, $C_{13}H_{27}COOH$.

Oxyacids, or Hydroxyacids, contain an alcohol group (OH) in addition to the (COOH) characteristic of the acid.

Lactic Acid, $CH_3CHOH\ COOH$. Formed in the fermentation of milk sugar by the *bacterium lactis.* A colorless, odorless syrup with acid taste, soluble in water and in alcohol.

Tests for lactic acid. 1.—Add an equal volume of sulphuric acid and a little potassium permanganate. On warming, the odor of aldehyde is produced.

2.—Add dilute (colorless) neutral, ferric chloride solution. A canary-yellow color is developed.

Sarco-lactic Acid, an isomer of ordinary lactic acid, is found in the muscle tissue in fatigue and after death.

Oxybutyric Acid, $C_2H_5CHOHCOOH$. A pathological ingredient of the urine. See under Urine.

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Dibasic Acids.

Oxalic Acid, $H_2C_2O_4$ or $(COOH)_2$. Occurs in many plants in the form of the potassium and sodium salts (*e. g.*, in rhubarb, in tomatoes, in sorrel). A crystalline acid with strong poisonous properties, soluble in water and in alcohol. For tests, see page 64.

Tartaric Acid, $H_2C_4H_4O_6$ or $(CHOHCOOH)_2$. Made from argol, impure cream of tartar, $KHC_4H_4O_6$. Large translucent monoclinic prisms, or as a white powder. Permanent in air. Soluble in water and in alcohol. For tests, see page 66.

Tribasic Acid.

Citric Acid, $H_3(C_6H_5O_7).H_2O$ or $C_3H_4OH(COOH)_3 + H_2O$. Occurs in lemons, oranges, etc. Made from lemon juice. Colorless crystals which effloresce in dry air, and deliquesce in moist air. Soluble in water and in alcohol. For tests, see page 62.

Ethers.

The ethers may be regarded as oxides of the hydrocarbon radicals.

Ethyl Ether, $(C_2H_5)_2O$. (Sulphuric or Common Ether.) Made by the action of concentrated sulphuric acid on an excess of alcohol.

$$C_2H_5OH + H_2SO_4 = C_2H_5HSO_4 + H_2O.$$

Alcohol. Ethyl acid sulphate.

$$C_2H_5OH + C_2H_5HSO_4 = (C_2H_5)_2O + H_2SO_4.$$

A colorless, volatile, inflammable liquid, with characteristic odor and a burning, sweetish taste. Specific gravity 0.75 at 25° C., soluble in 10 parts of water. Mixes with alcohol, chloroform, and the oils, in all proportions.

Tests for purity of ether.—Ether boils at about 35.5° C. (absolute ether boils at 34.97° C.). It should, then, boil if it be poured on some broken glass in a test-tube and held for some time tightly grasped in the hand. Should not affect the color of litmus paper; should leave no residue and should give no foreign odor on evaporation. Twenty c.c. of ether mixed with 20 c.c. of water previously saturated with ether, should show not less than 19.2 c.c. of ether after separation of the two liquids. Shaken with one-tenth part of potassium hydroxide solution, there should be no color in either liquid after one hour.

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ETHERIAL SALTS OR ESTERS. (METHANE SERIES.)

Etherial salts or esters are combinations of the hydrocarbons with acids. They are usually made by heating together an alcohol and an acid in the presence of an excess of sulphuric acid. Many esters have fruit-like odors and by blending them, artificial flavors are made.

ETHYL NITRITE, $C_2H_5NO_2$. A very volatile yellow liquid made from sodium nitrite, alcohol and sulphuric acid.

$$2NaNO_2 + 2C_2H_5OH + H_2SO_4 = 2C_2H_5NO_2 + Na_2SO_4 + 2H_2O.$$

Spirit of Nitrous Ether or *Sweet Spirit of Nitre* consists of ordinary alcohol with 4 per cent. of ethyl nitrite. This is a clear, volatile, pale yellow, inflammable liquid, with fragrant odor and sharp taste.

AMYL NITRITE, $C_5H_{11}NO_2$. A colorless, or slightly yellow, volatile inflammable liquid with characteristic odor. Almost insoluble in water, mixes with alcohol in all proportions.

ETHYL SULPHATE, $(C_2H_5)_2SO_4$. A heavy liquid which, when mixed with an equal volume of ether, forms the *Etherial Oil* of the U. S. P. This mixture with 13 parts of ether and 26 parts of alcohol, constitutes *Compound Spirit of Ether* (U. S. P.).

ETHYL ACETATE, $C_2H_5C_2H_3O_2$ (Acetic Ether). A colorless, inflammable liquid with fragrant odor and burning tasfe.

GLYCERYL NITRATE, $C_3H_5(NO_3)_3$. (Nitroglycerin.) A 1 per cent. solution of this in alcohol is official under the name of Spirit of Glyceryl trinitrate. Formerly known as Spirit of Glonoin.

The FATS and the FIXED OILS are etherial salts, formed by the union of glycerin, a triatomic alcohol, with the higher monobasic acids.

The WAXES are etherial salts formed by the union of the higher monatomic alcohols with the higher monobasic acids.

THE FATS AND FIXED OILS.

The fat of adipose tissue is a mixture of the glycerides of palmitic, stearic and oleic acids, the trivalent glyceryl radical uniting with three univalent acid radicals, thus:—glycerol, $C_3H_5(OH)_3$; glyceryl, $(C_3H_5)^{III}$; palmitic acid, $HC_{16}H_{31}O_2$; palmitin, the fat $= C_3H_5(C_{16}H_{31}O_2)_3$. In the same way are formed the glycerides of stearic acid, $HC_{18}H_{35}O_2$, and oleic acid, $HC_{18}H_{33}O_2$.

Olein is a liquid fat, palmitin and stearin are solid, stearin having the higher melting-point. The greater the proportion of olein

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present the more liquid will be the fat; the greater the proportion of stearin, the more solid the fat. In the adult human body the fats are fluid during life, the body temperature being 37° C. and the mixture of fats present melting at about 26° C.

Butter fat is a complex mixture of glycerides, containing about 85 per cent. of the non-volatile acids, stearic, palmitic, oleic and myristic (C_{14}) along with the volatile acids, butyric (C_4), caproic (C_6), caprylic (C_8), and capric (C_{10}). All of these acids, with the exception of oleic, have the general formula, $HC_nH_{2n-1}O_2$.

The fats vary in specific gravity from 0.91 to 0.97. They are insoluble in water and, generally, in cold alcohol, but are soluble in boiling alcohol, in chloroform, in ether, and, generally, in benzine and other petroleum products. Strongly heated they yield pungent, irritating fumes of acrolein. Decomposition of fat by putrefactive organisms results in the formation of propionic, acetic and formic acids—the fat becomes rancid.

LECITHIN, a complex fat containing phosphorus, is found in nerve tissue, in cell protoplasm, and in the bile and blood. On decomposition it yields glycerol, stearic acid, cholin, and phosphoric acid.

OILS differ from the solid fats in their greater proportion of olein and of other fats with low melting-points, and in their consequent fluidity at ordinary temperatures. As examples of the oils may be mentioned:

Castor Oil (*Oleum ricini*), a mixture of olein and ricinolein, $C_3H_5(C_{18}H_{33}O_3)_3$, with palmitin, etc. It is an almost colorless, viscid liquid, soluble in alcohol and in an equal volume, but not in an excess, of benzine. A drop of concentrated sulphuric acid added to a few drops of the oil spread upon porcelain produces a brown coloration with a yellow margin.

Olive Oil (*Oleum olivae*) consists chiefly of olein with palmitin, arachidin, cholesterol, and some albuminous matter. It is a pale greenish-yellow liquid with characteristic odor, sparingly soluble in alcohol, readily soluble in benzine, ether and chloroform. With sulphuric acid (see under castor oil) the coloration produced has a brownish center and an olive-green margin.

Cod Liver Oil (*Oleum morrhuæ*) is a mixture of olein with palmitin, myristin, and other more obscure compounds. It is a pale yellow, thin, oily liquid, easily soluble in ether and chloroform, but nearly insoluble in alcohol. With sulphuric acid (see under

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castor oil) the coloration produced has a reddish-brown center and more or less of a purple margin.

Tests for Fats. 1.—Sudan III. a red stain, insoluble in water, soluble in alcohol; stains fat but no other substance.

2.—Osmic acid (1 per cent. aqueous solution) stains olein black, but does not affect other fats.

Test of Melting-Point.—Heat some beef-fat in a dry dish avoiding too high a temperature, and filter the melted fat obtained through dry filter paper. A one-fourth inch glass tube is closed at one end by fusion and the cooled, solid fat introduced. The tube is then fastened to the bulb of a thermometer and suspended with it in a beaker of water, care being taken that no water enters the tube. The temperature of the water is gradually raised, and the temperature at which the fat softens is noted. This will be between 40° and 50° C.

The various *oils and fats are identified* by the specific gravity; by the "acid-number"—the number of milligrammes of potassium hydroxide required to neutralize one gramme of oil; by the "saponification number"—the number of milligrammes of potassium hydroxide required to saponify one gramme of oil; by the iodine absorption; by the refractive index, and by special tests.

To distinguish Butter fat from Oleomargarine, etc. Half fill a 100 c.c. beaker with fresh whole milk, heat nearly to boiling and add 5–10 grammes of the fat. Stir with wooden rod about the size of a match-stick until the fat is dissolved. Set the beaker in cold water and continue the stirring until the fat is coagulated. Butter fat will remain granular while oleomargarine, lard, etc., will collect in lumps. (Waterhouse.)

More reliable tests must, however, be resorted to before a positive opinion can be expressed.

Reichert's process is based upon the determination by distillation of the volatile fatty acids present. The volatile acids from 2.5 Gm. of melted butter require about 12 c.c. of decinormal sodium hydroxide for neutralization. Oleomargarine requires about 0.9 c.c., Cacao butter about 3.7 c.c. and lard about 0.6 c c.

Soaps.

Decomposed by ferments, by superheated steam, or by an alkali or metallic oxide, the fats yield glycerin and either the free fatty acid or a metallic salt of that acid known as a soap. The "sapon-

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ification" of a fat with formation of a "soft" potash soap may be indicated as follows:

$$C_3H_5(C_{18}H_{33}O_2)_3 + 3KOH = 3KC_{11}H_{33}O_2 + C_3H_5(OH)_3.$$
Olein. Potassium oleate. Glycerin.

The ordinary soaps are soluble in water, but when added in excess the solution becomes turbid from a partial decomposition, free alkali and an insoluble acid salt being liberated. By addition of mineral acids the soap is decomposed and the fatty acid set free.

$$KC_{18}H_{33}O_2 + HCl = HC_{18}H_{33}O_2 + KCl.$$

By addition of sodium chloride a "soft" potash soap may be transformed into a "hard" soda soap.

$$KC_{18}H_{33}O_2 + NaCl = NaC_{18}H_{33}O_2 + KCl.$$

By the addition of other metallic salts the soda soap may be further transformed.

Saponification and Soap Tests.—Warm 10 c.c. of castor oil (or of olive oil) in a porcelain dish, and add slowly, with constant stirring, 10 c.c. of a 10 per cent. sodium hydroxide solution. Continue the heating and stirring until the mass begins to thicken, then set aside to cool.

In making the test on so small a scale, the hard white soap obtained with castor oil is generally more satisfactory than the flaky "Castile Soap" (*Sapo, U. S. P.*) obtained with olive oil.

Dissolve some of the soap in hot water and place in 6 test-tubes. 1.—Note the lather produced on shaking. 2.—Add $CaCl_2$, and note that no lather is produced on shaking, but that an insoluble lime soap is precipitated. 3, 4 and 5.—Add, respectively, $FeCl_3$ $CuSO_4$, and $Pb(C_2H_3O_2)_2$. Note the formation of iron, copper and lead soaps. 6.—Add a few drops of conc. hydrochloric acid and note the separation of the fatty acids. Warm, and the acids rise to the top of the liquid like oil.

Soft Soap, Sapo Mollis, U. S. P.—Heat 400 grammes of linseed oil to 70° C., and add slowly, while stirring, a warm solution of potassium hydroxide (95 grammes, in water, 450 c.c., mix thoroughly and add 40 c.c. alcohol). Continue the heating and stirring until a portion of the soft mass will dissolve in boiling water without separation of oily drops. The test may be satisfactorily made on the small scale, using proportionate amounts of oil and alkali.

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Halogen Derivatives of Methane Series.

CHLOROFORM, $CHCl_3$. (Trichlormethane.) Prepared, 1.—By the action of an alkali on chloral.

$$2CCl_3COH + Ca(OH)_2 = 2CHCl_3 + Ca(CHO_2)_2$$

Chloroform Calcium formate

2.—By the action of "bleaching powder" on acetone.

$$2(CH_3)_2CO + 6CaOCl_2 = 2CHCl_3 + 2Ca(OH)_2 + Ca(C_2H_3O_2)_2 + 3CaCl_2$$

Properties. A heavy colorless liquid with characteristic sweetish odor. Boils at 60–61° C., specific gravity about 1.486, soluble in 200 parts water, and, in all proportions, in alcohol, ether, fixed and volatile oils. Decomposes gradually on exposure to light. As impurities may be found, alcohol, aldehyde, mono- and di-chlor derivatives, and hydrochloric acid.

Tests for chloroform. 1.—To some alcoholic potassium hydroxide in a test tube add a few drops of aniline, and one or two drops of chloroform, or of the solution to be tested. Warm gently; the disagreeable odor of phenyl-isocyanide, C_6H_5NC, is produced.

2.—A strip of paper moistened with chloroform, when ignited, burns with a greenish flame, and gives off fumes of hydrochloric acid.

3.—Heat some of the liquid with Fehling's solution. Red cuprous oxide is precipitated as in the test for dextrose (q. v.).

4.—Evaporate an alcoholic solution of phenol and potassium hydroxide, and to the hot residue add a few drops of chloroform, or of the liquid to be tested. A reddish-purple color is developed.

Tests for purity of chloroform.—Should yield no foreign odor on evaporation. Shaken with water the latter on evaporation should be neutral to litmus and should not be affected by addition of silver nitrate or of potassium iodide. With barium hydroxide in a corked tube, on standing for several hours in a dark place, there should be no film at the contact of the two liquids. Shaken with one-tenth part of strong sulphuric acid, and allowed to stand, the chloroform should remain colorless and the acid should not be more than faintly colored.

BROMOFORM, $CHBr_3$. (Tribrom-methane.) A heavy liquid similar to chloroform, agreeable odor, boils at 151° C.

IODOFORM, CHI_3. (Tri-iodomethane.) Prepared by the action of iodine on a mixture of sodium or potassium hydroxide, or car-

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bonate, and alcohol. (See test 2, under alcohol.) A lemon-yellow powder of characteristic odor, nearly insoluble in water, soluble in 46.7 parts cold alcohol, more soluble in hot alcohol, in ether, chloroform, and the oils.

ETHYL CHLORIDE, C_2H_5Cl. (Monochlorethane.) A volatile, inflammable liquid, boiling at 12.5–13° C. Used in production of local anæsthesia.

ETHYL BROMIDE, C_2H_5Br. An inflammable liquid, boiling at about 40° C.

Metallic Derivatives of Paraffin Hydrocarbons.

CACODYL, $As_2(CH_3)_4$; CACODYL OXIDE, $As_2(CH_3)_4O$; CACODYLIC, ACID, $As(CH_3)_2O.OH$. With zinc we have $Zn(C_2H_5)_2$, with mercury, $Hg(C_2H_5)_2$, etc.

ETHYLENE AND ACETYLENE SERIES AND DERIVATIVES.

Compared with the methane series, the ethylene and acetylene series contain but few important compounds.

OLEFIANT GAS, C_2H_4 (Ethene, or Ethylene), is a gas similar to methane but burning with a luminous flame. It is a constituent of illuminating gas.

ACETYLENE, C_2H_2 (Ethine, or Ethinene). A gas with characteristic odor and high illuminating power. May be made by the reaction between calcium carbide, CaC_2, and water.

$$CaC_2 + 2H_2O = C_2H_2 + Ca(OH)_2.$$

Derivatives, Ethylene Series—ALLYL ALCOHOL, C_3H_5OH, yields, on oxidation, ACRYLIC ALDEHYDE OR ACROLEIN, C_2H_3COH, and this, by further oxidation, ACRYLIC ACID, C_2H_3COOH, the first of the Acrylic acid series, to which belongs OLEIC ACID, $C_{17}H_{33}COOH$ (see under Fats, page 103).

Among the sulphur derivatives of the ethylene series we have the Mustard Oils.

In the *Acetylene Series*—LINOLEIC ACID, $C_{15}H_{27}COOH$, characteristic of Linseed Oil.

THE BENZENE OR AROMATIC SERIES AND DERIVATIVES.

The carbon atoms of the benzene molecule are usually considered as being arranged in a closed hexagonal chain—*The Benzene Ring*, with one atom of hydrogen connected with each atom of carbon, and the alternate carbon atoms united by two units of valency.

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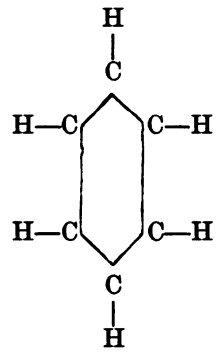
Diagrammatically this is expressed



The carbon atoms are numbered 1 to 6; and derivatives are considered as formed by replacing particular atoms of hydrogen. If two hydrogen atoms are replaced we have three isomeric compounds possible—the *ortho-*, where the atoms replaced were adjacent; the *para-*, where they were opposite; the *meta-*, where they were alternate.

The first three members of this series are, Benzene, or Benzol, C_6H_6, Toluene, or Toluol, C_7H_8, Xylene, or Xylol, C_8H_{10}.

BENZENE, C_6H_6 (Benzol). Prepared from coal-tar. A colorless, limpid, highly refractive liquid, boiling at 80.4° C. Insoluble in water, soluble in 4 parts alcohol, and in ether. Inflammable, used as a solvent.

TOLUENE and XYLENE are similar to Benzene.

NAPHTHALENE, $C_{10}H_8$, is obtained from coal tar by distillation between 180° C. and 220° C., and separates from the oils in white glistening crystals. It melts at 79° C. and large quantities are moulded into the well-known "moth balls" or "coal tar camphor." Chemically it may be considered as formed by the union of two benzene molecules.

BETANAPHTHOL, $C_{10}H_7OH$, a valuable antiseptic, is prepared from naphthalene.

Anthracene, $C_{14}H_{10}$, is obtained from coal tar by distilling above 360° C. Chemically it may be considered as formed by the union of three benzene molecules.

Alizarin, $C_6H_4(CO)_2C_6H_2(OH)_2$, an important base for the manufacture of many dyes is prepared from anthracene.

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THE VOLATILE OR ESSENTIAL OILS include the Terpenes, $C_{10}H_{16}$, and the Cedrenes, $C_{16}H_{26}$.

TURPENTINE (Terebinthina). A yellowish, opaque oleoresin obtained from species of the Pine family, separates on distillation into a solid, rosin, and

OIL OF TURPENTINE, $C_{10}H_{16}$. A thin, colorless liquid, with characteristic odor and taste, lighter than water, practically insoluble in water, soluble in 3 parts alcohol. Boils at about 160° C. Derived from oil of turpentine are Terebene and Terpin Hydrate.

Oxidation products of the Volatile Oils include the RESINS, and these, dissolved in complex mixtures of oils, forms the BALSAMS. The GUM RESINS are mixtures of resins with the plant sugars. Allied to the resins we have CAMPHOR, $C_{10}H_{16}O$, a tough white translucent substance with characteristic odor and taste, very sparingly soluble in water, soluble in alcohol, etc., and in the oils. Camphor may be pulverized in presence of a little added alcohol or ether. MENTHOL, $C_{10}H_{20}O$, is similar to camphor. Occurs in colorless acicular crystals having the odor of peppermint. Sparingly soluble in water, soluble in alcohol.

PHENOLS.

The Phenols are formed by replacing hydrogen of the benzene molecule with hydroxyl (OH). They are isomeric with the alcohols, but differ in not yielding aldehydes and acids on oxidation, and in not reacting with acids to form esters. The phenols are monatomic, diatomic, triatomic, etc., according to the number of hydroxyl groups present.

PHENOL, C_6H_5OH. (Carbolic Acid, Phenic Acid.) Prepared commercially from coal-tar, and, also, from benzene. Forms in a colorless mass of needle-like crystals, sometimes turning pink on exposure to light. Has a characteristic odor, whitens and cauterizes the skin; soluble in 19.6 parts water at 25° C., very soluble in alcohol, ether, glycerin, and the oils. Melts when heated and liquefies on addition of about 8 per cent. of water. *Liquefied Phenol*, U. S. P., is prepared by melting the phenol on a water-bath and then adding, for each nine parts of phenol, one part of water. Liquefied phenol is soluble in about 12 parts water. It begins to solidify at about 13.5° C.

Tests for phenol. 1.—Note the characteristic odor, and the greasy stain upon paper.

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2.—Heated with excess of strong nitric acid the solution turns yellow, trinitrophenol (picric acid), $C_6H_2(NO_2)_3OH$, being formed.

3.—A few drops of ferric chloride impart a violet-blue color to the solution. Alcohol should be absent.

4.—Add a few drops of the solution to a little concentrated hydrochloric acid in a test-tube, then add one drop of dilute nitric acid and warm gently. A purple-red color is developed.

5.—Mix the solution with one-quarter volume of ammonia water, add a few drops of sodium hypochlorite solution and warm. A bluish-green color is developed, turning to a red on addition of hydrochloric acid.

6.—The addition of bromine water produces a precipitate of tribromphenol, $C_6H_2Br_3OH$, soluble in excess of phenol.

7.—Add a few drops of Millon's reagent (see Appendix) and heat to boiling; an intense dark red color is obtained.

PHENATES or CARBOLATES are formed by replacing the hydrogen of the hydroxyl group in phenol. *E. g.*, Sodium phenate, C_6H_5ONa.

SULPHOCARBOLATES, or PHENOLSULPHONATES, are salts of Phenolsulphonic Acid, $C_6H_4OHSO_3H$. The sodium and zinc salts are official.

TRINITROPHENOL, $C_6H_2(NO_2)_3OH$. (Picric Acid.) Made by the action of nitric acid on phenol. A yellow crystalline substance, with an intensely bitter taste, soluble in water, more soluble in alcohol.

CRESOL, $C_6H_4CH_3OH$. The phenol derived from Toluene. A colorless or straw-colored refractive liquid, with odor resembling that of phenol. A mixture of the three isomeric cresols is known as trikresol.

CREOSOTE. Obtained from wood-tar, the best from beech-wood. A mixture of phenols and phenol derivatives, chiefly guaiacol, $C_6H_4OCH_3OH$, and creosol, $C_6H_3CH_3OCH_3OH$. An almost colorless, or yellowish, highly refractive liquid, with smoky odor and burning taste. Samples which turn brown on exposure are not suitable for medicinal purposes.

Tests for creosote. 1.—It should dissolve in 120 parts of hot water, the solution becoming turbid on cooling (difference from, and absence of, both phenol and coal-tar creosote).

2.—One volume of creosote with one volume of glycerin (95

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per cent.) forms a clear liquid from which a creosote layer, equal to, or greater than, the original volume of creosote, will separate on adding one-fourth volume of water (difference from, and limit of, phenol).

3.—On adding to 10 c.c. of a saturated, aqueous solution of creosote, one drop of neutral ferric chloride, a transient violet-blue color is obtained, clouding instantly, and the color changing to a grayish-green, a brown, and finally, a brown precipitate is obtained (difference from phenol and coal-tar creosote, and limit of the former).

COAL-TAR CREOSOTE, an impure carbolic acid from coal-tar.

THYMOL, $C_6H_3(C_3H_7)CH_3OH$. A derivative of cresol, forms in large translucent crystals of aromatic odor and taste.

THYMOL IODIDE, $(C_6H_2C_3H_7CH_3OI)_2$. ("Aristol.") A reddish-yellow or chocolate-colored powder, with slight aromatic odor, insoluble in water and glycerin, slightly soluble in alcohol.

"CREOLIN." Saponified coal-tar creosote.

"LYSOL." Saponified coal-tar cresol.

PYROCATECHOL, RESORCINOL, and HYDROQUINONE, are the isomeric, ortho-, meta-, and para-, diatomic phenols, with the formula $C_6H_4(OH)_2$.

GUAIACOL, $C_6H_4OCH_3OH$. A colorless crystalline solid, derived from pyrocatechol.

PHLOROGLUCINOL, PYROGALLOL, and OXYHYDROQUINONE, are isomeric-triatomic phenols, with the formula $C_6H_3(OH)_3$.

ALDEHYDES. (BENZENE SERIES)

BENZALDEHYDE, C_6H_5COH. (From benzyl alcohol, $C_6H_5CH_2OH$, compare with the isomeric cresol.) A colorless, highly refractive liquid, the main constituent of Oil of Bitter Almonds.

ACIDS. (BENZENE SERIES.)

BENZOIC ACID, C_6H_5COOH. Prepared from benzoin by sublimation or, synthetically, from naphthalene. White or yellowish-white shiny scales or needles, soluble in hot water and in alcohol. Odorless if pure, though that from benzoin has a characteristic odor. The Benzoates are generally easily soluble in water.

Tests for benzoic acid. 1.—Heated with 3 parts freshly slaked lime, benzene is evolved.

2.—Dissolve in a solution of sodium hydrate, carefully neutral-

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ize and add diluted neutral ferric chloride. Flesh-colored ferric benzoate is precipitated.

SALICYLIC ACID, $C_6H_4(OH)COOH$. Made from Oil of Wintergreen or, synthetically, from phenol. Fine white needles, odorless, or with a faint odor of wintergreen, soluble in hot water and in alcohol. The Salicylates are generally easily soluble in water. For tests, see page 66.

GALLIC ACID, $C_6H_2(OH)_3COOH$. White or fawn-colored, silky, odorless crystals.

ETHERIAL SALTS. (BENZENE SERIES.)

METHYL SALICYLATE, $C_6H_4(OH)COO(CH_3)$. The main constituent of Oil of Wintergreen or Gaultheria Oil, and Oil of Birch.

PHENYL SALICYLATE, $C_6H_4(OH)COO(C_6H_5)$. ("Salol.") A white crystalline powder very slightly soluble in water, soluble in alcohol and in the oils.

Sulphur Derivatives of Benzene Hydrocarbons.

Among the complex sulphur derivatives of the benzene hydrocarbons we have "Aseptol," "Asaprol," "Saccharin," and "Ichthyol."

BENZOSULPHINIDUM, U. S. P. "SACCHARIN," $C_6H_4.SO_2.CO.NH$, is a white powder estimated to be about 500 times sweeter than cane sugar. Soluble in 400 parts water.

"ICHTHYOL" is a thick brown liquid obtained by distillation from bituminous shale. Soluble in water, in glycerin, and the oils; insoluble in undiluted alcohol.

Nitrogen Derivatives of Benzene Hydrocarbons.

NITROBENZENE, $C_6H_5NO_2$. (Artificial Almond Oil.) A liquid with odor of oil of bitter almonds.

ANILINE OR PHENYLAMINE, $C_6H_5NH_2$. Made by the action of nascent hydrogen on nitrobenzene. An oily, colorless, or yellowish-brown liquid used as the basis of a great many "coal-tar" colors.

The coal-tar colors can be detected by the following method:

Dissolve from 10 to 20 grams of the sample in 100 c c. of water, filter if necessary, acidify with from 2 to 4 c.c. of a 10 per cent. solution of hydrochloric acid. In this solution immerse a piece of woolen cloth, which has been washed in a very dilute solution of boiling potassium hydroxide and then washed in water, and boil for from 5 to 10 minutes. Remove the cloth, thoroughly wash it in water,

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and boil in a very dilute hydrochloric acid solution. After washing out the acid dissolve the color in a solution of ammonium hydroxide (1:50). With some of the dyes solution takes place quite readily while with others it is necessary to boil for some time. Take the wool out, add a slight excess of hydrochloric acid to the solution, immerse another piece of wool, and boil it again.

With vegetable coloring matter this second dyeing gives practically no color, and there is no danger of mistaking a fruit color for one of coal-tar origin. It is absolutely necessary that the second dyeing should be made, as some of the coal-tar dyes will dye a dirty orange in the first acid bath which might be easily passed for vegetable color, but after solution in alkaline bath the second acid bath dyes a bright pink.

ANILIDES. Formed from aniline by substituting for the hydrogen of the NH_2 group.

ACETANILIDE, $C_6H_5NH(C_2H_3O)$. ("Antifebrin.") Colorless, odorless, crystalline powder, with a slight burning taste. Soluble in 179 parts water, and in 2.5 parts alcohol.

ACETPHENETIDIN, $C_6H_4(OC_6H_5)NHC_2H_3O$. ("Phenacetine.") White crystalline powder; odorless and tasteless. Soluble in 925 parts water, and in 12 parts alcohol.

PHENYLDIMETHYLPYRAZOLON, $C_6H_5N(COCH)(CH_3NCH_3C)$. ("Antipyrine.") Colorless, almost odorless, crystalline powder, with slight bitter taste, soluble in less than 1 part water, and in 1 part alcohol.

HYDRAZINES, formed by substituting for the hydrogen of the hydrazine group, N_2H_4. *E. g.*, Phenylhydrazine, $N_2H_3(C_6H_5)$.

INDOLE, C_8H_6NH, and SKATOLE, $C_8H_5CH_3NH$, leaf-like crystalline substances, with fecal odor, characteristic of the feces. Excreted, in part, in the urine as potassium indoxysulphate or Indican, $C_8H_6NKSO_4$, and as potassium skatoxylsulphate, $C_8H_5CH_3NKSO_4$. For tests, see under Urine.

DIMETHYLAMIDOAZOBENZOL, $C_6H_5.N.C_6H_4N(CH_3)_2$, PHENOLPHTHALEIN, $C_6H_4CO.OC(C_6H_4OH)_2$, and METHYLORANGE, $NaC_{14}H_{14}N_3SO_3$, are all benzene derivatives and used extensively as indicators.

Pyridine and Quinoline Bases. (Pyridine, C_5H_5N, and Quinoline, C_9H_7N.) Related to or included with these bases are many of the alkaloids.

ALKALOIDS. (See, also, page 72.)

Related especially to the Pyridine bases are *Piperine* (Pepper); *Coniine* (Conium maculatum); *Nicotine* (Tobacco); *Sparteine*

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(Scoparius, Broom); *Atropine* (Atropa belladonna); *Hyoscyamine* and *Hyoscine* (Hyoscyamus niger); *Cocaine* (Erythroxylon coca); The Cinchona group, *Quinine*, *Quinidine*, *Cinchonine*, and *Cinchonidine*; *Strychnine* and *Brucine* (Strychnos nux vomica, etc.); *Veratrine* (Asagraæ offinalis).

Related to Quinoline are the alkaloids of the Opium group, *Morphine*, *Codeine*, *Narcotine*, and *Narceine*; *Hydrastine* and *Berberine* (Hydrastis canadensis).

The Xanthine alkaloids include *Caffeine* (Coffee) and *Theobromine* (Theobroma cacao).

Among the unclassified alkaloids are *Physostigmine* or *Eserine* (Calabar bean); *Aconitine* (Aconite); *Colchicine* (Colchicum).

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THE CARBOHYDRATES.

The carbohydrates are compounds of carbon, hydrogen and oxygen, with the latter two elements in the ratio of 2:1 and generally with six, or a multiple of six, atoms of carbon.

They may be classified as follows:

Monosaccharids.	*Disaccharids.*	*Polysaccharids.*
$C_6H_{12}O_6$.	$C_{12}H_{22}O_{11}$.	$(C_6H_{10}O_5)_n$.
Dextrose (Glucose),	Sucrose (Cane Sugar),	Cellulose,
Levulose (Fructose),	Lactose (Milk Sugar),	Starch,
Galactose,	Maltose (Malt Sugar),	Granulose,
		Dextrin,
		Glycogen.

Chemically the monosaccharids may be considered as aldehydes and ketones derived from the hexatomic alcohol, $C_6H_8(OH)_6$. The di- and poly-saccharids may be regarded as anhydrides of the monosaccharids.

By oxidation, carbohydrates are converted into mannitic acid, $HC_6H_{11}O_7$, and, by further oxidation, into saccharic acid, $H_2C_6H_8O_8$, tartaric acid, oxalic acid and carbonic acid. By oxidation in presence of an alkali, carbohydrates are converted into glucic, $C_{24}H_{18}O_{18}$, and melassic acids, $C_{12}H_{10}O_5$. By oxidation within the body, glycuronic acid, $C_6H_{10}O_7$, is produced.

Dextrose. (Glucose, Grape Sugar.)

A white powder, more or less crystalline, or, usually, as a thick syrup, soluble in water, less soluble in alcohol, insoluble in ether. It is sweet to the taste, but less so than cane sugar. Made from starch by boiling with dilute acids.

$$\underset{\text{Starch.}}{C_6H_{10}O_5} + H_2O = \underset{\text{Dextrose.}}{C_6H_{12}O_6}.$$

Dextrose is found in fruits, in honey, and, in small amount, in

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the various fluids of the body. In diseased conditions it may appear in the body fluids in largely increased amount.

Owing to its aldehyde nature ($CH_2OH.(CHOH)_4.COH$) dextrose is capable of acting as a reducing agent especially with alkaline solutions of copper or silver. It rotates the plane of polarized light to the right, and this property is utilized in the polariscope, to determine the percentage strength of dextrose solutions.

Tests:—

1.—*Moore's Test.*—Add to a dilute solution of dextrose, one-half volume of sodium hydroxide, and heat to boiling. A brown coloration is obtained. Add a little nitric acid, the color disappears in part and the characteristic odor of caramel is given off.

2.—*Picric Acid Test.*—Add to the solution a few drops of picric acid and a little sodium hydroxide. Heat the mixture and a mahogany-brown color is developed.

3.—*Silver Test.*—To some silver-ammonium nitrate add a few grains of glucose. When dissolved, heat to boiling. The solution darkens and a metallic mirror of silver is formed at the bottom of the tube. Tartaric acid and the aldehydes give the same test.

4.—*Fermentation Test.*—To the solution in a test-tube add a small piece of dry yeast and invert the tube over mercury. After standing for 24 hours in a warm place, carbonic anhydride gas will be found to have accumulated at the top of the tube. The liquid may be tested for alcohol. It is well to make a control test with yeast and pure water in a second test-tube.

This test is usually made in an Einhorn's apparatus which is graduated to give the per cent. of glucose in a solution by measuring the amount of carbon-dioxide formed during fermentation.

5.—*Böttger's Test.*—To the solution of dextrose in a test-tube add solution of sodium hydroxide and then a few grains of bismuth subnitrate. Mix the solution well and boil. A black precipitate of metallic bismuth is formed. Sodium carbonate may be used in place of sodium hydroxide.

6.—*Trommer's Test.*—Add an excess of solution of sodium hydroxide, and then a solution of copper sulphate drop by drop, until a *slight* permanent precipitate is formed. In the presence of dextrose the bluish-white precipitate of cupric hydroxide, first formed, dissolves on agitation, producing a dark blue solution. Heat the liquid and, in presence of glucose, yellow cuprous hydroxide and red cuprous oxide are precipitated just as the liquid

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begins to boil. The same precipitation occurs, but much more slowly, in the cold.

7.—*Phenylhydrazin Test.*—To 50 c.c. of the solution add two grammes of phenylhydrazin hydrochloride, and four grammes of sodium acetate. Dissolve the salts by agitation and warm on the water-bath for 45 minutes. If glucose be present, on cooling, if not before, a yellow crystalline precipitate of glucosazone will separate out.

The crystals will appear under a magnifying glass in the shape of needles arranged in bundles. They may be further identified by determining their melting-point which is about 205°C.

This test is an excellent one, as it does not depend upon the reducing properties of dextrose but upon the formation of a definite compound. Milk sugar and malt sugar also form similar products, lactozone and maltozone, having melting points of 200°C and 207°C respectively.

8.—*Haines' Test.*—Heat 5 c.c. of Haines' solution in a test-tube, then add a few drops of the solution to be tested and again heat. A reddish-yellow precipitate indicates a reducing sugar. This solution should be carefully made, and reasonably fresh.

9.—*Fehling's Test, Qualitative.*—Fill a test-tube one-third full of Fehling's solution No. 1 and then add an equal volume of Fehling's Solution No. 2. Mix well and heat to boiling. The solution should remain clear and of a deep blue color. Add a few drops of the solution to be tested, mix and heat the test-tube only in the upper portions. Note if there is any discoloration by comparing the appearance of the heated portion with the lower portion. Add a few more drops of the solution to be tested and again heat. If no change in color is noted test the reagents by adding a few drops of a known solution of dextrose. A yellow precipitate is characteristic of a reducing sugar and will always be produced with a dilute solution of dextrose if the reagents are in proper condition.

Quantitative.—To exactly 5 c.c. of Fehling's solution No. 1 in an Erlenmeyer flask add exactly 5 c.c. of Fehling's solution No. 2 and then about 40 c.c. of distilled water. Place flask in boiling water and after two minutes add from a burette one or two cubic centimetres of the solution in which the dextrose is to be estimated. Boil for five minutes and if color is still blue add more of the solution to be tested and boil again. Continue adding the solution until all of the blue color disappears. Repeat the entire operation

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with fresh solutions until the exact number of cubic centimetres required to completely remove all of the blue color is determined. This number of cubic centimetres will contain 0.05 Gm of dextrose and from this data the percentage amount can be calculated.

It is sometimes difficult to tell just when all of the blue color is removed but if the flask be held on a level with the eye the color of the upper layer can be observed.

Where more accurate results are desired the Fehling's solution should be in excess, the flask immersed in boiling water for fifteen minutes and the cuprous oxide then collected and weighed.

10.—*Pavy's and Purdy's solutions.* These tests are made practically as with Fehling's solution, with this difference that Pavy's and Purdy's solutions both contain a sufficient amount of ammonium hydroxide to redissolve the cuprous oxide formed and the end point is thus more easily observed.

The blue color from 50 c.c. of Pavy's solution, used undiluted, is removed by 0.025 Gm. of dextrose. The blue color from 35 c.c. of Purdy's solution which should be diluted with 70 c.c. of water before use is removed by 0.02 Gm. of dextrose.

11.—*Barfoed's Test.*—Boiled with Barfoed's reagent (see Appendix) solutions of glucose cause a precipitation of red cuprous oxide.

Levulose (Fructose), and Galactose.

Levulose is very similar to dextrose, differing from it principally in its action on polarized light, being lævo-rotatory while dextrose is dextro-rotatory. It is less easily crystallized and, in the body, occurs only in traces. Chemical tests are the same as for dextrose.

Invert Sugar is a mixture of dextrose and levulose obtained by the action of acids and of certain ferments on cane sugar.

Galactose is formed by the action of acids and of ferments on lactose. It resembles dextrose closely, but differs in being soluble in absolute alcohol.

Sucrose. (Cane Sugar.)

A white crystalline solid, easily soluble in water, insoluble in absolute alcohol and in ether. It occurs in large amount in sugar cane, sugarbeet and maple sap. Sucrose is an important food, each gramme yielding 4.1 calories of heat. The consumption of sucrose per capita is about 85 lbs a year in the United States.

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Tests :—

1.—To a little sugar in a test-tube add strong sulphuric acid and warm gently. The sugar is charred.

2.—Heat some sugar on a piece of platinum foil. It melts, darkens, chars, and burns, giving off inflammable gases and the characteristic odor of caramel.

3.—To a solution of sugar add a little sodium hydroxide and warm. If the sugar be pure there will be no change of color. (Compare with dextrose.)

4.—Warmed with strong nitric acid, sugar is converted into saccharic, tartaric, and, finally, oxalic acid, red fumes of nitrogen oxides being evolved. A similar reaction is given with other carbohydrates.

5.—Cane sugar does not reduce Fehling's Solution; with Trommer's Test a blue solution is obtained, but there is no reduction, except by prolonged boiling, when a slight precipitation may occur with either Fehling's or Trommer's.

6.—By the action of yeast and, also, by boiling with dilute acids, cane sugar is converted into dextrose and levulose. To a dilute solution of sugar, add a little hydrochloric acid and boil for several minutes. Cool the solution and apply Trommer's Test.

$$\underset{\text{Cane Sugar.}}{C_{12}H_{22}O_{11}} + H_2O = \underset{\text{Dextrose.}}{C_6H_{12}O_6} + \underset{\text{Levulose.}}{C_6H_{12}O_6}.$$

7.—Pure sucrose gives negative results with Barfoed's reagent.

Lactose. (Milk Sugar.)

Prepared from milk by removing the fat and the curd and evaporating the whey. A white crystalline solid, less soluble in water than cane sugar or dextrose, insoluble in alcohol or ether. It possesses only a faint sweet taste.

Lactose responds to most of the tests for dextrose; it reduces Fehling's solution, though less strongly than dextrose, and answers to Trommer's test. It differs from dextrose in not directly undergoing alcoholic fermentation with yeast (commercial samples often ferment rapidly), and by giving negative results with Barfoed's test. In the phenylhydrazin test the crystals obtained are larger than with dextrose. By the lactic acid micro-organism, as in the ordinary souring of milk, lactose is converted first into lactic acid and then into butyric acid, but by certain other ferments, and by

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boiling with acids, it is changed into galactose which may then undergo ordinary alcoholic fermentation. Lactose may be separated from skim milk by acidulating with dilute acetic acid, filtering off the coagulated caseinogen and evaporating the filtrate.

MALTOSE.

A white, crystalline substance, soluble in both water and alcohol, produced by the action of diastatic ferments on starch. Like lactose it responds to nearly all of the tests for dextrose. Its reducing power with Fehling's Solution is one-third less than that of glucose, while its dextro-rotation of polarized light is more than twice as great. It readily undergoes alcoholic fermentation, and by prolonged boiling with water, or more easily by boiling with dilute acids, it is converted into dextrose.

Maltose resembles lactose but may be differentiated by means of the fermentation test. It differs from glucose, in giving a negative result when boiled with Barfoed's reagent.

STARCH. (AMYLUM).

A white, inodorous, tasteless substance, insoluble in ether, alcohol, or cold water. Under the microscope it appears in uniform granules of characteristic appearance. Found in all plants, most abundantly in the root, soft parts and seeds.

Tests :—

1.—Add a few grains of starch to a little sodium hydroxide in a test-tube. Note that the starch swells and forms a thick paste in the cold.

2.—Prepare some starch paste as follows: Add sufficient powdered starch to water in a test-tube to form a milky fluid. Pour this milky fluid into a beaker of *boiling* water. Note that the milky appearance disappears. Dilute some of the "paste" so formed with water, put aside sufficient for Tests 3, 4 and 5, and to the remainder, when cool, add a few drops of iodine solution. A blue color is produced. Divide this blue solution into three parts: (*a*) Heat one part carefully until the color disappears. Upon cooling, the color will again develop. If carefully performed this may be repeated several times. (*b*) To the second prrt, add a few drops of sodium hydroxide. The blue color is destroyed, but may be reproduced by the addition of dilute hydrochloric acid. (*c*) To the third part, add mercuric chloride. The blue color is destroyed.

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3.—Starch is insoluble in cold water, or in alcohol. When heated with water it is partially dissolved, the soluble portion being known as *granulose*, the insoluble portion, as *starch-cellulose*. To some of the clear starch solution obtained in (2) add alcohol. The granulose is precipitated.

4.—To some of the solution obtained in (2) add dilute hydrochloric acid and heat to boiling. Test a small portion of the solution in another test-tube, with iodine. If the boiling has been sufficient no color will appear, showing the conversion of the starch into dextrose and dextrin.

$$2C_6H_{10}O_5 + H_2O = C_6H_{12}O_6 + C_6H_{10}O_5.$$

The dextrin first produced gives a red or brown coloration with the iodine.

5.—By the action of diastatic ferments, starch is converted into maltose and dextrin.

$$3C_6H_{10}O_5 + H_2O = C_{12}H_{22}O_{11} + C_6H_{10}O_5.$$

Mix a little of the diluted starch-paste, prepared in (2), with saliva, or better with some commercial preparation of a diastatic ferment, *e. g.*, with Taka-diastase, and warm to about the temperature of 40° C. At intervals test a drop of the mixture with a drop of iodine solution on a porcelain plate. The blue color first obtained, indicating starch, will gradually give place to a brownish-red color due to erythrodextrin. No color with the iodine shows conversion of the starch into achroodextrin. The presence of maltose may be proved by Fehling's test, q. v., both starch and dextrin being non-reducing.

Dextrin.

An amorphous substance, readily soluble in water, insoluble in alcohol and in ether, produced by hydrolysis of starch and other amyloses. There are two varieties, *erythrodextrin* which gives the iodine test below, and *achroodextrin* which does not give the iodine test. *Pure* dextrin is non-reducing, and does not undergo fermentation with yeast.

1.—Drop some of the aqueous solution into alcohol; a white precipitate is formed.

2.—A drop of iodine solution added to a solution of dextrin gives a reddish-brown coloration which disappears when the solution is heated, but reappears on cooling.

3.—Basic lead acetate gives no precipitate. (Unlike glycogen.)

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4.—Boiling with dilute hydrochloric acid converts dextrin into dextrose.

5.—*Pure* dextrin reduces neither Fehling's nor Barfoed's reagent.

Glycogen.

A white or yellowish-white tasteless amorphous powder, insoluble in alcohol or ether, imperfectly soluble in boiling water. It is present in the tissues of the body, abundantly in embryonic tissue.

Glycogen is an important constituent of the liver, where it is stored mainly for the use of the muscles. It is made available by a ferment when needed. Glycogen may be obtained by boiling perfectly fresh liver in a one per cent. solution of sodium hydroxide for two hours, neutralizing and filtering.

Tests:—

1.—With iodine, glycogen gives a deep red color when in solution, a brown color when in form of powder. On heating the solution the color disappears, but reappears on cooling.

2.—With sodium hydroxide and one or two drops of copper sulphate a blue coloration is obtained, but there is no precipitate on boiling. (See Trommer's test, under Dextrose.)

3.—Basic lead acetate precipitates glycogen from its aqueous solution. (Unlike dextrin.)

4.—Boiling with dilute hydrochloric acid converts glycogen into dextrose.

Cellulose.

Cellulose is a complex colloid substance, closely related to starch and probably formed from it.

Prepared by reducing vegetable tissues to a pulp and washing out the starches, gums and salts present.

Cotton-wool, which is nearly pure cellulose, is suitable for most of the tests.

Tests:—

1.—To some cotton in a test-tube add a little sodium hydroxide. Warm the mixture and let it stand. Note that the fibres swell slightly and become more or less gelatinous.

2.—To a second sample add concentrated sulphuric acid and warm gently. Note that the cotton turns brown or black, and goes partially or entirely into solution.

3.—Dissolve some pure cellulose in a solution of cupric ammonium hydroxide. Then add hydrochloric acid carefully until the

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blue color of the solution is destroyed, and note that the cellulose is precipitated in a stringy mass.

4.—Cellulose is insoluble in water, alcohol or ether.

5.—Boil some sawdust with 5 per cent. sulphuric acid for an hour, replacing frequently the water lost by evaporation. Add calcium carbonate to neutralize the excess of acid and filter. Evaporate filtrate and taste residue. Make several tests for dextrose.

Cellulose treated with a mixture of nitric and sulphuric acids yields tetra- and penta-nitrates (*pyroxylin*) which dissolve in a mixture of ether and alcohol to form *collodion*. To 40 grammes of pyroxylin add 750 c.c. of ether, let stand 15 minutes, add 250 c.c. alcohol and shake until solution is complete. Longer treatment of cellulose with the acids yields cellulose hexa-nitrate, *gun cotton*, $(C_6H_7O_2)_2(NO_3)_6$, insoluble in ether and alcohol. *Celluloid* is a solution of pyroxylin in camphor.

Gums.

Certain vegetable gums are included among the carbohydrates, *e. g.*, gum arabic, gum senegal, gum tragacanth, pectin, pectose, algin, and agar-agar.

THE GLUCOSIDES.

The glucosides are substances, chiefly of vegetable origin, which on decomposition by the action of dilute acids, or by ferments, yield as one of the products a carbohydrate, generally glucose.

Example. Amygdalin, $C_{20}H_{27}NO_{11}$, found in bitter almonds, peach kernels, etc., on decomposition by action of the ferment emulsin, yields, as products, benzaldehyde, hydrocyanic acid and glucose.

Other glucosides are Digitalin, Salicin, Saponin, Esculin, Glycyrrhizin, and Arbutin.

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THE PROTEINS.

THE proteins occur in both the vegetable and animal kingdoms, more abundantly in the latter. They all contain carbon, hydrogen, oxygen and nitrogen; most of them contain sulphur, and phosphorus is present in a few. Various formulæ have been calculated for the simpler proteids, but little, however, is known regarding their true constitution. They vary in composition as follows (Hoppe-Seyler):

	C	H	N	S	O
From	51.5	6.9	15.2	0.3	20.9
To	54.5	7.3	17.0	2.0	23.5

On decomposition the proteins yield ammonium compounds, amides, fatty acids, amido-acids, aromatic compounds, etc. In normal body metabolism the final products are carbon dioxide, water, and urea.

All proteins are insoluble in alcohol. Some are soluble in water, others are not. Many not soluble in water are soluble in dilute saline solutions. Some are soluble in concentrated saline solutions, others are insoluble. All are soluble when heated with strong acids, and all are soluble, after change, in the gastric and pancreatic juices. Many of the proteins can, with difficulty, be obtained in the crystal form, but all are colloids, that is, non-diffusible, a property attributed generally to the large size of their molecules. All are levorotatory.

TESTS FOR PROTEINS.

Proteins are usually identified by one or more of the following reactions, each of which is due to the presence of a certain organic group or combination of groups in the molecule.

1.—*Xantho-proteic Reaction.*—To a little of the solution in a test-tube, add a few drops of concentrated nitric acid and heat to boiling. A yellow color is produced. Cool, and render the solu-

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tion alkaline with sodium hydroxide. An orange-yellow color is obtained.

This reaction depends upon the formation of certain nitro derivatives, and is referable to the presence in the molecule of a tyrosin group ($C_6H_4.OH.CH_2.CH.NH_2.COOH$) or an indol complex. It is accordingly not characteristic of proteins alone.

2.—*Millon's Reaction.*—To the solution add an equal quantity of Millon's Reagent (see Appendix). The white precipitate first formed turns red on heating. The presence of sodium chloride interferes with this reaction.

This reaction is common to all benzene derivatives in which one hydrogen atom has been replaced by a hydroxyl group. This radical is absent in gluten and in a few albumoses, and these bodies accordingly do not give this reaction.

3.—*Biuret Reaction.* (Piotrowski's.)—Render the solution alkaline with sodium hydroxide and add one or two drops of dilute copper sulphate; a violet coloration is obtained. With peptones the color obtained is rose-red.

The resulting color is due to the formation of biuret potassium cupric oxide, and is dependent upon the presence in the albuminous molecule of the group $CO.NH.CH_2.NH_2$, and is, therefore, also obtained with certain non-albuminous substances.

4.—*Adamkiewicz Reaction.*—Float the albuminous solution over a mixture of 1 part concentrated sulphuric acid and 2 parts acetic acid; warm gently. A purple color is developed at the contact, increasing in intensity on standing.

This is a furfurol reaction, and has been generally ascribed to the combined presence of a carbohydrate group and a tyrosin radical.

ESTIMATION OF PROTEINS. In estimating proteins quantitatively the nitrogen in organic combination is determined, and this amount is then multiplied by 6.25.

Kjeldahl-Gunning Method.—By this method all of the nitrogen of the protein molecule is formed into ammonia, and this is then combined with sulphuric acid. An excess of alkali is added and the ammonia is distilled over into standard sulphuric acid, where its amount may be determined by titrating the excess of acid with standard alkali.

Place from 0.7 to 3.5 grammes of the material, according to the probable amount of nitrogen present, in a 500-c.c. Kjeldahl flask, add 10 grammes of powdered potassium sulphate and about 20 c.c. of concentrated sulphuric acid. Place flask in hood over a small gas flame and gradually increase heat until the contents of the flask appear perfectly clear. Cool and dissolve residue in 300 c.c.

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of distilled water, cool in ice water, add a few drops of Congo-red solution, and then sufficient cold saturated solution of sodium hydroxide to render the mixture strongly alkaline. Connect the flask with a condenser and distil until two-thirds of the contents have passed over. Collect the distillate in a beaker containing a measured amount of standard sulphuric acid. The excess of sulphuric acid, that unneutralized by the ammonia, is then determined by titrating with a standard alkali solution, using Congo-red as the indicator.

Example:—2 grammes of the sample treated as above and distilled into 25 c.c. of $\frac{N}{10}$ H_2SO_4. Suppose 15 c.c. of $\frac{N}{10}$ NaOH are required to neutralize the excess of acid—then 10 c.c. of the $\frac{N}{10}$ H_2SO_4 must have been neutralized by the ammonia. Now 10 c.c. $\frac{N}{10}$ H_2SO_4 will be neutralized by 0.01693 gramme of ammonia, representing 0.01393 gramme of nitrogen. If there be 0.01393 gramme of nitrogen in 2 grammes of the material, there must be 0.696 gramme in 100 grammes. The sample therefore contains 0.696 per cent. of nitrogen, and this is equivalent to (0.696 × 6.25) 4.35 per cent. of protein.

Classification of Proteins.

Owing to the complexity of these compounds and the incomplete knowledge of their chemical relations a perfect system of classification has not been devised. The following, however, has been temporarily adopted by many chemists:

1. Protamins.
2. Histons.
3. Albumins
   - Lac-albumin
   - Serum albumin
   - Ovalbumin.
4. Globulins
   - Lac-globulin
   - Serum globulin
   - Ova-globulin.
5. Sclero-proteins
   - Keratin
   - Elastin
   - Collagen
     - Ossein
     - Chondrogen.
6. Phospho-proteins.
7. Conjugate proteins
   - Chromo-proteins
   - Gluco-proteins
     - Mucins
     - Mucoids
     - Chrondro-proteins.
   - Nucleo-proteins.
8. Protein derivatives
   - Infra-proteins
   - Proteoses
   - Peptones.

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Protamins.

The protamins are considered the simplest of the proteins, and yield only a small number of amino-acids on hydrolysis. They do not coagulate on heating; they respond to the biuret reaction, and are not precipitated by ammonia.

Histons.

The histons stand chemically between the protamins and the albumins, more closely resembling the latter. They are precipitated by ammonia, are basic, and many contain iron. *Globin* and *nucleohiston* are examples of this class.

Albumins.

Albumins are soluble in water, in dilute saline solutions, and in saturated solutions of sodium chloride and magnesium sulphate. They are coagulated by heat, egg-albumin at about 73° C., and are precipitated by saturation with ammonium sulphate.

1.—Mercuric chloride precipitates white albuminate of mercury.

2.—Copper sulphate precipitates blue albuminate of copper.

3.—Add to the solution a few drops of acetic acid and then a little potassium ferrocyanide. A precipitate is formed.

4.—*Picric Acid Test.*—Add to the solution a few drops of picric acid; a precipitate is formed.

5.—*Tannic Acid Test.*—Add to the solution a few drops of a solution of tannin. A precipitate is formed.

6.—*Nitric Acid* forms a white precipitate if not added in excess.

7.—*Nitric Acid Contact Test.*—Place about one inch of strong nitric acid in a test-tube, and float over it carefully, so as to avoid admixture, some of the solution to be tested. In the presence of albumin, a white cloudy ring, or zone, will form at the contact of the two liquids.

8.—*Acidulated Brine Test.*—Place the acidulated brine (see Appendix) in a test-tube, and float over it the solution to be tested. A white precipitate is formed at the contact of the two liquids.

9.—*Tanret's Test.*—Place the Tanret's Solution (see Appendix) in a test-tube, and float over it the solution to be tested. A white precipitate is formed at the contact of the two liquids.

10.—*Trichloracetic Acid Test.*—Add some of the crystals to the solution to be tested, and allow them to dissolve without agitation at the bottom of the tube. A white precipitate is formed.

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11.—*Heat Test.*—Heat some of the aqueous solution of albumin just to boiling. The albumin is coagulated, forming a white precipitate. The solution should be slightly acid or should contain sodium chloride. The temperature at which the coagulation takes place averages between 60° C. and 75° C.

12.—Burn a small fragment of solid albumin on a piece of platinum foil. Note the characteristic odor of burnt horn.

Egg- and serum-albumin may be readily distinguished by the following tests:

Egg-Albumin.	*Serum-Albumin.*
1.—Rapidly precipitated by alcohol.	1.—Slowly precipitated by alcohol.
2.—Precipitated by ether.	2.—Not precipitated by ether.
3.—Readily precipitated by HCl, the precipitate not dissolving in excess.	3.—Not readily precipitated by HCl, the precipitate dissolving easily in excess.

Tests for Sulphur in Albumin.—1.—Heat a solution of lead acetate in a test-tube and add sodium hydroxide until the white precipitate of lead hydroxide, first formed, *is just* redissolved. Boil the clear liquid, and, while boiling, add a little albumin solution. The mixture turns brownish-black from the formation of lead sulphide.

2.—Heat a little of the solid albumin in a tube, and hold in the mouth of the tube a piece of paper moistened with lead acetate. The paper is blackened by the fumes evolved.

3.—Boil some albumin solution with a few grains of bismuth subnitrate and an excess of sodium hydroxide. A brownish-black precipitate of sulphide of bismuth is formed.

Globulins.

The globulins resemble the albumins in being soluble in dilute saline solutions, in being coagulated by heat, and in being precipitated by ammonium sulphate. In the latter case, however, half saturation (add equal volume of saturated ammonium sulphate solution) suffices to precipitate globulins, while for the precipitation of albumins full saturation with crystals of ammonium sulphate is required. Unlike the albumins, they are insoluble in pure water and insoluble in concentrated solutions of sodium chloride, or of magnesium sulphate.

Serum-Globulin, also known as fibrinoplastin and paraglobulin,

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is the principal globulin of the blood. *Fibrinogen* is that substance which, under the influence of a ferment, gives rise to the fibrin of clotted blood. The active portion of snake venom, and the remedial portion of antitoxin sera are either globulins or intimately connected therewith.

Scleroproteins.

As important members of this class we have, *Collagen*, from the white connective tissue; *Ossein*, a collagen from the bones; *Gelatin*, derived from collagen by boiling with water; *Chondrin*, similar to gelatin, derived from the *Chondrigen* of the cartilages; *Elastin*, from the yellow elastic fibres, *Eleiden* and *Keratin*, from the epidermis, hair, nails, etc., and *Lardacein* or *Amyloid Substance.*

Gelatin.

Formed by hydrolysis of collagens. When dried and pulverized bones are digested with dilute hydrochloric acid, the mineral salts are dissolved and ossein left behind. This last heated with water is rapidly converted into the substance gelatin. Test the properties of gelatin as follows:

1.—Try the action of cold water. The gelatin swells without dissolving.

2.—Warm the mixture and it will be found that the gelatin dissolves. Divide this solution into two parts:

(*a*) Allow one part to cool in a test-tube, and note that on cooling the solution "gelatinizes."

(*b*) Boil the remainder of the solution for several minutes, and then let it cool. Note that now it does not gelatinize.

3.—To the solution obtained in 2, b, or to a fresh solution of gelatin, apply the following tests:

(*a*) The Xanthoproteic test gives a lemon-yellow color.

(*b*) The Biuret test gives the usual violet color.

(*c*) Millon's and Adamkiewicz's tests are negative in results with *pure* gelatin.

(*d*) Mercuric chloride, hydrochloric acid and picric acid give precipitates from strong solutions.

(*e*) Nitric acid and acetic acid give no precipitate.

Phosphoproteins.

The phosphoproteins contain phosphorus but do not contain a carbohydrate group. *Caseinogen* is an important member of this class.

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Conjugate Proteins.

These include three classes, the chromoproteins, the glucoproteins and the nucleoproteins.

The *chromoproteins* are found mainly in the blood.

The *glucoproteins* when heated with dilute mineral acids yield a simple protein and a glucose-like substance which will reduce Fehling's solution. There are three types:—(a) *Mucin*, which occurs in the secretions of the mucous glands, and which is precipitated by acetic acid but not coagulated by heat. (b) *Mucoids*, which are not precipitated by acetic acid. (c) *Chondroproteins*, which may be split into chondroitin and a carbohydrate combined with an ester of sulphuric acid.

The *nucleoproteins* by hydrolysis are split into a protein and a nuclein, which latter may again be split into another protein and a nucleic acid.

Protein Derivatives.

Acid and alkali-albumins, the so-called albuminates or *infraproteins*, are derived from albumins and globulins by the action of weak acids and alkalies. They are soluble in acids and alkalies, and in dilute saline solutions, but are precipitated by saturation with neutral salts. They are not coagulated by heat.

1.—To an albuminous fluid add a considerable amount of acetic acid. An *acid-albumin* is formed. Boil, and note that there is no coagulation.

(a) Apply the Xanthoproteic reaction to part of the solution obtained in 1.

(b) Add carefully, to another part of the same solution, dilute sodium hydroxide, and note that when the acid is just neutralized the albumin will be precipitated.

2.—To the albuminous fluid add a few drops of sodium hydroxide and warm the mixture. An *alkali-albumin* is formed. Boil the solution and note that there is no coagulation.

(a) Apply the Biuret test to part of the solution obtained in 2.

(b) Add carefully, to another part of the same solution, acetic acid, and note that when the sodium hydroxide is just neutralized the albumin will be precipitated.

The *proteoses* or *albumoses* are classed as primary or secondary, depending upon the stage of hydrolysis. They are intermediate products in the cleavage of the protein molecule into peptone.

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The *peptones* are the final products in the hydrolysis of proteins. They are soluble in water, are not coagulated by heat, and are not precipitated by either ammonium sulphate or nitric acid. They are precipitated by alcohol, mercuric chloride, phosphomolybdic acid and tannin.

By further cleavage of the peptone molecule various *amido-acids* are obtained.

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FERMENTS AND FERMENTATION.

MANY chemical changes are caused by certain substances called *ferments*, which may be present in exceedingly small quantities not bearing any quantitative relation to the products formed. Their action is similar to that of *catalyzing agents* which incite certain chemical reactions by their presence. Thus, a small piece of platinum sponge will cause large volumes of sulphur dioxide and oxygen to combine, though none of the platinum is consumed in the operation. In like manner a small amount of pepsin will cause the transformation of a large amount of albumin into peptone.

Bacterial cells are frequently considered as responsible for many of these chemical transformations, but it has been shown that the cell is merely the parent of the material which actually brings about the change in question. Based upon the older belief, however, we still often divide the ferments into two classes, the organized and the unorganized.

The *Organized ferments* are associated with living cells, the multiplication of which is accompanied by changes in the substances upon which they feed. In this chemical metamorphosis complex compounds are resolved into simpler forms.

As examples of the more simple reactions of this class we have the conversion of glucose into alcohol and carbon dioxide by the yeast plant (*Saccharomyces cerevisiæ*), the change of lactose into lactic acid by the *Bacillus acidi lactici*, the change of urea into ammonium carbonate by the *Micrococcus ureæ*. More complex are the changes in the putrefaction of organic matter by such organisms as the *Bacillus subtilis*. In many cases the products of the reaction are specific poisons, as is instanced by the bacilli of anthrax, of septicæmia, diphtheria, typhoid, etc., etc. *Ptomaines* are basic substances formed by decomposition of dead material. *Leucomaines* are similar to ptomaines, but are products of normal metabolism. *Toxins* are poisonous substances, generally of pro-

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tein nature, elaborated by the growth of certain micro-organisms. *E. g.*, Tetanus toxin from *Bacillus tetani.*

In the putrefaction of albumin we have an instance of the great complexity of certain of the decompositions. Among the products of the bacterial action here we find: peptones; ptomaines such as peptotoxine, neuridine, neurine, choline, cadaverine, putrescine, etc.; nitrogenous bases, such as leucin, tyrosin and amines; formic, acetic, propionic, butyric, valerianic, palmitic, lactic and succinic acids; indol, phenol, cresol, pyrocatechol, hydroquinol, etc., etc.; finally, hydrogen sulphide, ammonia, carbon dioxide and water.

The *Unorganized ferments* or *Enzymes* are amorphous, protein substances, originating in animal and vegetable cells. They exist within the cell in an inactive state, as *Zymogens* or *Proenzymes*, becoming active when liberated, either by the ordinary life process or by bruising or crushing the organ. They are present in all body cells, as is shown by the autolysis, or autodigestion, of aseptic tissue after death, an action which may be prevented by heating to 70–80° C. They are soluble in water, insoluble in alcohol, and may be extracted from their source by water, by salt solution, or best, by glycerol.

Owing to a lack of knowledge of their chemical relationship, ferments are usually classified in accordance with the kind of chemical change they incite.

I. *Amylolytic:* Ptyalin, amylopsin, diastase. Change amyloses into sugars. (Polysaccharids into mono- and disaccharids.)

II. *Proteolytic:* Pepsin, trypsin, papain. Change albumins, etc., into peptones.

III. *Steatolytic:* Steapsin. Decomposes fats into fatty acids and glycerol.

IV. *Inverting Enzymes:* Invertin. Changes cane sugar, etc., into glucoses. (Disaccharids into monosaccharids.)

V. *Glucoside-decomposing Enzymes:* Emulsin and myrosin.

VI. *Coagulating Enzymes:* Chymosin, thrombin, rennin, myosin ferment. Coagulate protein compounds.

VII. *Oxidizing Enzymes:* Oxidase and peroxidase.

The first five classes are hydrolytic in action. By hydrolysis starch is converted into maltose and dextrin; saccharose splits up into glucose and levulose; maltose into two molecules of glucose; lactose into glucose and galactose. Albumin splits up into two molecules of albumose, etc.

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The oxidizing ferments are but little known. Oxidase makes available the atmospheric oxygen (O_2), and is found in plants alone. Peroxidase makes available only atomic oxygen (O), and is found in both plant and animal tissue. The tissue ferment which sets free the atomic oxygen, *e. g.*, from the oxyhemoglobin of the blood, is known as a Catalase.

It will be observed that many of the enzymes belong to the class of digestive ferments. These will be referred to in more detail in the discussion of the digestive fluids.

Controlling Influences in Fermentation.—The living ferments and the enzymes are both generally easily killed by a moist heat of 100° C., but when perfectly dry many will stand a temperature of from 100° C. to 160° C. They are rendered quiescent, but are not killed by exposure to cold. A temperature of 35°–40° C. is generally the most favorable to both classes. Alcoholic fermentation is especially favored by a temperature of 15°–20° C.; acetic fermentation, by a temperature of 20°–25° C.; and lactic fermentation, by a temperature of 35°–40° C. Arsenous oxide, phenol, salicylic acid, chloroform and ether will kill many of the organized ferments, but generally have a less destructive action upon the enzymes. Most of the enzymes find their most favorable environment in a neutral medium, or in one that is faintly alkaline; pepsin, however, requires a neutral or acid medium. Papain is active in either acid, alkaline or neutral media.

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PART III.

PHYSIOLOGICAL AND CLINICAL CHEMISTRY.

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THE CHEMICAL COMPOSITION OF THE BODY.

APPROXIMATELY the body would show, on ultimate analysis, the following percentage composition:

Oxygen,	66.0	78.6	96.1	98.6
Hydrogen,	10.2			
Nitrogen,	2.4			
Carbon,	17.5			
Calcium,	1.6			
Phosphorus,	0.9			

Other elements present in the order of their abundance, are potassium, sodium, chlorine, sulphur, magnesium, iron, iodine, fluorine, and silicon. These elements are combined, approximately, as follows:

Water,	65 per cent.
Proteins,	15 "
Fats,	14 "
Salts,	5 "

Together with carbohydrates, acids, and extractives.

The WATER varies in amount in the different tissues from 0.2 per cent. in the enamel of the teeth, to 50 per cent. in the bones, 70–75 per cent. in the muscles and glandular organs, 86 per cent. in the brain, and 99.5 per cent. in the saliva.

Of the SALTS, calcium phosphate forms about three-fourths. Other salts are the chlorides, sulphates, phosphates and carbonates, of potassium, sodium, magnesium and calcium. In the bones the calcium salts predominate; in the solids, except the lungs, the potassium salts, and in the fluids, except the milk, the sodium salts.

The FATS are chiefly stearin, palmitin and olein.

The PROTEINS include: 1. The albumins and globulins and the substances derived from them—the proteoses, peptones, albumi-

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nates, etc., found chiefly in the fluids of the body. 2. The conjugate proteins; the nucleo-proteins, mucin, hemoglobin, etc., found chiefly in the cells of the body. 3. The scleroproteins; the collagens, ossein, chondrigen, elastin, eleidin, keratin, etc., found chiefly in the connective and supporting tissues of the body.

Other substances present in small amounts are the carbohydrates, dextrin, glycogen, dextrose, maltose, lactose; glycuronic acid, traces of acetic, butyric, succinic and other acids; traces of alcohols, including cholesterol; lecithin, indole, skatole, inosite, glycocin, leucin, tyrosin, urea, sarcosin, creatine, creatinine, taurin, cystin, glycocholic acid, taurocholic acid, uric acid, xanthine, and various ferments.

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FOOD.

WATER, Inorganic Salts, Carbohydrates, Fats, and Proteins are necessary to furnish the body heat, to supply energy and to repair body waste.

Water is obviously required. The *Mineral Salts* are needed in furnishing material for bones and in replenishing the salts that are being constantly eliminated.

The *Carbohydrates* and *Fats* supply heat and muscular energy, and the carbohydrates may, also, partially be transformed into fat and stored as such in the body as a reserve material.

The *Proteins* are utilized in repairing waste and in building new protein substances. They may also furnish heat and muscular energy, but are not especially adapted for these purposes, as the amido acids, which are formed, are not easily eliminated.

Protein is more expensive than any other essential food material, and therefore the most economic diet, as well as the best physiologic one, consists of protein in just sufficient amount to replenish the waste, together with sufficient carbohydrate and fat to supply the energy needed.

There are two systems of diet calculation in general use:

(1) *The Percentage System*, which is based upon the amounts of the essential food elements required as determined by examination of the excreta, etc. For instance, according to Voit the daily ration of an adult man should consist of 118 Gms. proteins, 500 Gms. carbohydrates, and 56 Gms. fats. An adult woman requires 94 Gms. proteins, 400 Gms. carbohydrates, and 45 Gms. fats.

(2) *The Caloric System*, which is based upon the number of heat units, *Calories*,* needed to supply the necessary heat and muscular energy.

The caloric value of any food is conveniently determined by

* A *Calorie* is the amount of heat required to raise the temperature of 1000 Gms. of water from 0° to 1° C.

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means of a *Parr calorimeter*, which consists of a water-jacketed insulated jar, into which the dried food is placed along with sodium peroxide. After closing the jar, and adjusting a delicate thermometer, an electric spark is passed through the peroxide. The foodstuff is consumed, raising the temperature in proportion to the caloric value of the material.

1 Gm. of protein produces 4.1 Calories of heat.

1 Gm. of carbohydrate produces 4.1 Calories of heat.

1 Gm. of fat produces 9.3 Calories of heat.

An adult requires about 2500 Calories of food each day, of which about 40 Gms., or 164 Calories, must be protein.

The number of Calories may easily be computed in any food, if its composition is known, by multiplying the percentage of fat by 9.3 and the percentages of carbohydrate and protein by 4.1. The sum of these products will be the number of Calories in 1 Gm. Multiply this result by 453.6 to obtain the number of Calories in each pound.

Food.	Water.	Protein.	Fat.	Carbo-hydrate.	Ash.	Calories in Each Pound.
Round steak.	65.5	19.7	12.9	—	0.8	950
Liver	71.2	20.4	4.3	1.7	1.2	620
Chicken.	74.8	20.9	2.4	—	0.8	520
Oysters.	83.4	8.5	2.3	3.9	1.1	340
Eggs (boiled)	73.2	12.8	11.4	—	0.6	755
Rice	12.3	6.5	0.3	76.9	0.3	1610
Corn bread	38.9	6.5	4.2	45.2	1.7	1170
White bread.	35.3	7.1	1.2	52.3	0.8	1195
Brown bread	43.6	4.2	1.6	46.2	1.6	1035
Sugar.	—	—	—	100.0	—	1790
Butter	11.0	1.0	80.8	—	2.3	3410
Peanuts.	9.2	21.9	34.7	22.0	1.5	2255

A part of nearly every food is not digested, and a correction for this has been made in the table above.

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THE DIGESTION OF FOOD.

THE process of digestion, in outline, is as follows:

In the *Mouth* the food is masticated and mixed with saliva and air. The food is thereby moistened, the act of swallowing aided, and some of the soluble ingredients are dissolved. Chemically, the ptyalin of the saliva converts part of the starch into maltose and dextrin. Cellulose and uncooked starch are practically unacted upon. The mass is finally rolled into a "bolus" and swallowed.

In the *Stomach* the ptyalin action may continue for a variable time, stopping, finally, with the appearance of free acid in the gastric fluid. The chief function of the gastric juice is, by action of its ferment, pepsin, and its hydrochloric acid, the conversion of albumins (and globulins) into acid-albumins, into proteoses (albumoses and globuloses), and then into peptone. Gelatinous bodies swell and partially dissolve, certain salts are dissolved, while horny tissue, mucin, nuclein, cellulose, wax, sugars and gums, remain chemically unchanged. The semi-liquid mass is passed on, a little at a time, to the duodenum, where the pancreatic digestion begins.

In the *Duodenum*, by the action of the ferments of the pancreatic fluid, aided by the presence of the bile, the digestion begun by the salivary and gastric ferments is completed. Starch is converted by the amylopsin into maltose, dextrose, and dextrin. The albumins by the action of the trypsin, in the presence of alkali, are converted into alkali-albumin, albumose and peptone. Elastin and nuclein, and other protein substances, but little acted upon by the gastric fluid, are here more or less perfectly digested. Finally some of the peptones are further decomposed into leucin and tyrosin. The fats are emulsified, and, also, by the action of the steapsin, partially decomposed into glycerin and fatty acids, the latter being then rapidly converted into soaps.

Finally, in the *Intestines* we have the secretion of the intestinal glands containing, possibly, a ferment, invertin, which may be instrumental in converting disaccharids, cane sugar, etc., into monosaccharids, dextrose, etc. More important, probably, is the action of the organized ferments, the intestinal flora, in disintegrating and decomposing the remaining food residues.

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THE SALIVA.

THE saliva is the mixed secretion of the parotid, submaxillary, sublingual, and buccal glands. It is colorless, clear, or faintly opalescent, usually alkaline in reaction, and froths easily. It varies in specific gravity between 1.002 and 1.008, and contains from 0.5 to 1.0 per cent. of solid matter, the latter consisting of albumin, mucin, ptyalin, and mineral salts. In suspension the saliva contains epithelial cells, "salivary corpuscles," and lumps of mucus. The mineral matter includes the chlorides, bicarbonates, phosphates, and sulphates of sodium, potassium and calcium, with traces of other substances. On exposure to the air the carbonate of calcium is precipitated and the saliva becomes clouded.

The presence of Sulphocyanates can be demonstrated by adding to the saliva a small quantity of hydrochloric acid and a very dilute solution of ferric chloride, when a reddish color will be produced. Nitrites are sometimes present and may be identified by the blue color obtained on adding a little thin starch paste containing potassium iodide and then faintly acidulating with sulphuric acid.

The saliva contains large numbers of bacteria, such as *Bacillus maximus buccalis*, which turn blue with iodine; *Spirochaete buccalis*, which are abundant in tartar on teeth and are actively motile, also the *Staphlococcus pyogenes aureus* and *Bacillus subtilis*.

The amount of secretion varies, but is assumed to be from 1000 to 2000 c.c. in twenty-four hours.

The parotid saliva is watery, free from mucin, and is rich in ptyalin. The submaxillary saliva contains more mucin than the mixed, otherwise it is similar. The sublingual is the richest in solids, the most viscid, and the most alkaline of the three.

Ptyalin, the important amylolytic enzyme of the saliva, is similar to, but not identical with, malt diastase. It converts cooked starch into maltose and dextrin, has no action on uncooked starch grains, on cellulose, or on cane sugar. It acts slowly on glycogen. The ferment acts best in a neutral medium, at a temperature of

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from 35° to 40° C.; it is not killed by dilute alkalies, but its action is prevented entirely by the presence of more than a trace of free acid.

The complete transformation of starch to maltose is not completed by the saliva even by continued action. *Amylodextrin* which gives a blue with iodine, is first formed; then *Erythrodextrin*, which gives a mahogany-brown with iodine; and finally, *Achroodextrin*, *Maltodextrin* and *Maltose* which are not colored by iodine.

To demonstrate the properties of ptyalin, filter some saliva and at 40° digest with dilute starch paste for fifteen minutes, then test with iodine.

Saliva or sputum may be examined for bacteria by a method similar to that described in the chapter on Urine, under Urinary Sediments. The carbol-fuchsin stain is especially suitable for the determination of tubercle bacilli.

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THE GASTRIC FLUID.

THE gastric fluid is a thin, almost colorless liquid, with an acid reaction and a specific gravity of 1.001 to 1.010. The following analysis is given by Schmidt:

Water	994.404
Organic Substances, chiefly Pepsin . . .	3.195
Hydrochloric Acid	0.200
Sodium Chloride	1.465
Potassium Chloride	0.550
Other Inorganic Salts	0.186

The composition varies, however, during the digestive process and in disease. The average "total acidity" is probably between 0.10 and 0.50 per cent. The "free acid" is commonly stated as from 0.20 to 0.30 per cent., but with ordinary food the free acid will rarely exceed 0.10 per cent. The hydrochloric acid formed in the early stages of digestion combines rapidly with the proteins, and is not likely to be detected in the fluid before one-half hour after the meal. In fevers, in anemia, in catarrh of the stomach, etc., pepsin and hydrochloric acid may both be considerably reduced, or even absent (Achylia). Hydrochloric acid may be deficient (Hypochlorhydria), or absent (Achlorhydria) in serious diseases of the gastric mucous membrane, in atrophy, gastric cancer and chronic catarrh. On the other hand, it is often largely increased (Hyperchlorhydria) in gastric ulcers. In nervous dyspepsia the hydrochloric acid may be normal, increased, or decreased. Fat, butter, cream and milk reduce the amount of hydrochloric acid; a meat diet increases it.

Lactic acid is frequently present in very small amount and, under certain conditions, butyric and other organic acids may appear. As a result of excessive fermentative changes, lactic and butyric acids may appear in large amount. In such a case there is always a corresponding increase in gaseous products, the

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stomach is distended and gaseous eructations occur. Lactic acid is increased when secretion and peristalsis are deficient; it is characteristically increased in gastric carcinoma. Among the abnormal constituents of the vomit we may find excessive mucus, albumin, blood and bile, while in uremia, urea and ammonium carbonate are also often present.

Examination of Stomach Contents.

Physiologically in the morning before eating the stomach is empty or contains only from 10 to 20 c.c. of gastric fluid. More than 20 c.c. of fluid, the presence of food particles, the presence of Boas-Oppler bacilli, or of blood, would be considered as pathological.

To prepare the stomach contents for analysis a *test breakfast* is usually given, that most frequently adopted being the Boas-Ewald which consists of one roll and 300 c.c. of water. The stomach contents are removed after one hour.

To *measure the contents* of the stomach, the following method (Jaworski) may be used: With the stomach tube remove a portion of the contents, measure it (V) and determine its acidity (A). Introduce into the stomach a measured quantity of water (W), and mix it thoroughly with the stomach contents by raising and lowering the tube. Finally remove this wash water and determine its acidity (a). The volume of the original contents is then approximately equal to $V+\frac{Wa}{A-a}$.

Macroscopic Examination. — Note appearance, odor, color, the presence of mucus, remnants of undigested food and evidence of gaseous fermentation.

Reaction.—Filter through dry paper and test acidity with litmus, congo red, or tropæolin paper. These tests if positive must then be supplemented by the following :

Gunzberg's test for free hydrochloric acid.—Put one drop of the fresh reagent and one drop of the filtered gastric juice, on a small porcelain dish and carefully evaporate to dryness over a low flame or water-bath. If 0.005 per cent. of free hydrochloric acid be present a faint red will be visible while a larger quantity will produce a beautiful carmine-red, which is unaltered on the addition of ether.

Methyl-Violet Test.—To 5 c.c. of water add a drop of a solution of methyl-violet. Divide the test solution into 2 parts, and to one

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add an equal volume of filtered gastric fluid. Compare with the remainder of the test solution. A change in color, from violet to blue, indicates hydrochloric acid, but the delicacy of the test is destroyed by the presence of either pepsin or peptones.

Dimethylamidoazobenzol Test.—A one-half per cent. alcoholic solution of dimethylamidoazobenzol has been highly recommended as an indicator for free hydrochloric acid—in the presence of the acid the yellow of the solution is turned to magenta-red—but a similar color change is produced by acid phosphates and with many organic acids, *e. g.* from acetic, butyric, formic, lactic, malic, propionic and succinic.

TÖPFER'S QUANTITATIVE METHOD FOR TOTAL ACIDITY, FREE HYDROCHLORIC ACID, AND COMBINED HYDROCHLORIC ACID.

(A) *Total Acidity.* To 10 c.c. of filtered gastric fluid add 5 drops of phenolphthalein solution, then from a burette decinormal solution of sodium hydroxide until there is produced a faint pink which will not disappear on stirring—note the reading of burette and then continue adding the decinormal sodium hydroxide until one drop will produce no *increase* in depth of pink color. Multiply the number of cubic centimeters used by ten and the result represents the total acidity.

The first reading, taken when a permanent pink is produced, multiplied by ten represents the total acidity less that produced by the acid phosphates present. If the gastric fluid be saturated with sodium chloride before the titration is made the end points will be sharper.

(B) *Free Hydrochloric Acid.* To ten cubic centimetres of the filtered gastric fluid add five drops of dimethylamidoazobenzol solution; if free hydrochloric acid is present a bright red will be produced. Add from a burette decinormal sodium hydroxide until the red color disappears and a bright yellow color is formed. Multiply the number of cubic centimeters used by 10 and result represents the acidity due to free hydrochloric acid.

Where only a small amount of material is available a rough quantitative test can be made by saturating a filter paper with dimethylamidoazobenzol solution and touching it with a rod moistened in the fluid. If paper turns red dilute 1 drop of fluid with 1 drop of water and repeat test. Then make higher dilutions and repeat until the reaction no longer takes place. A dilution of 3–6 is normal.

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(C) *Combined acids.* To ten cubic centimetres of filtered gastric fluid add 5 drops of alizarin solution. From a burette add decinormal sodium hydroxide until a violet color is obtained. Multiply the number of cubic centimetres used by ten; the result is acidity due to free hydrochloric acid, acid salts, and organic acids.

Now the first titration, using phenolphthalein as the indicator, gives the free hydrochloric acid, acid salts, organic acids and combined acids; therefore subtracting the results of the alizarin titration from this, determines the amount of combined acid.

ORGANIC ACIDS, *Uffelmann's Test for Lactic Acid.*—To Uffelmann's reagent (see Appendix) add a little of the filtered gastric fluid. The amethyst-blue of the reagent is changed to a canary-yellow by lactic acid (1–10,000). Hydrochloric acid may decolorize the reagent, and butyric acid turns it reddish-brown.

Knapp's Test for Organic Acids.—One c.c. of the filtered gastric fluid is extracted with 5 c.c. of ether and the etherial solution floated over 2 c.c. of water to which has been previously added 1 drop of a 10 per cent. solution of ferric chloride. A canary-yellow ring at the contact indicates lactic acid; an orange-colored ring, butyric acid; a mahogany-brown ring, succinic acid.

The *amount of lactic acid* may be approximated by *Strauss's apparatus.* Put 5 c.c. of gastric fluid in apparatus and shake with 20 c.c. of ether. Discard all but 5 c.c. of the ether and shake this with 20 c.c. of water; add 2 drops of fresh neutral 10 per cent. ferric chloride and shake gently; 0.1 per cent. lactic acid will give an intense yellow-green; 0.5 per cent. a slight reaction.

Acetic and Butyric Acids. Add 2 grammes of sodium sulphate to 10 c.c. of gastric fluid and shake out three times with 50 c.c. of of acid-free ether. Evaporate to dryness and divide into two portions.

Test one portion for acetic acid by dissolving in a little water, neutralizing with dilute sodium carbonate solution and then adding a few drops of ferric chloride. A blood-red color, which becomes brownish on boiling, indicates acetic acid.

The second portion is dissolved in two or three drops of water and a very small fragment of calcium chloride added to solution. If an oily globule separates having the odor of rancid butter, butyric acid is indicated.

ACID SALTS. *Knapp's Test for Acid Phosphates.*—The reagent used is the red ferric sulphocyanate obtained by adding to 5 c.c. of

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water two drops of a 10 per cent. solution of ferric chloride, and 5 drops of a 5 per cent. solution of ammonium sulphocyanate. To test for the acid phosphates, 1 c.c. of the reagent is placed in each of two test-tubes, and to one the filtered gastric fluid is added, while to the other is added an equal amount of water. In the presence of acid phosphates the ferric sulphocyanate is either entirely or partially decolorized.

PROPEPTONE. Add to 5 c.c. of the gastric filtrate an equal amount of a saturated solution of sodium chloride. Propeptone, if present in large amounts may be precipitated. If no precipitate is formed then add 1 or 2 drops of acetic acid, and precipitation will occur if propeptone is present. On heating, the solution will clear, but it clouds again upon cooling.

PEPTONE. Filter out the propeptone and make strongly alkaline by adding sodium hydroxide solution, then a few drops of a 1 per cent. copper sulphate solution. Peptone gives a purple or violet-red color (Biuret reaction).

PEPSIN. A thin disc of the white of a hard-boiled egg, about 1 gramme, is placed in a test-tube containing 5 c.c. of the gastric filtrate and kept at blood temperature. This can be conveniently done by heating water to 40° C. temperature and putting it into a Thermos bottle; cork the test-tube and immerse. In testing for pepsin when free hydrochloric acid is absent, add 2 drops of dilute hydrochloric acid to the gastric filtrate, and keep at blood temperature as before. If pepsin is present the albumin will disappear in from two to six hours.

Ricin Test for Pepsin. Dissolve 1 gramme ricin in 100 c.c. of a 5 per cent. solution of sodium chloride and filter. Mix 2 c.c. of this filtrate with 0.5 c.c. decinormal hydrochloric acid solution; 1 c.c. of diluted stomach contents is added and allowed to remain at blood temperature for three hours. Ferments clear up the ricin deposit. The quantity of pepsin is determined from the amount of dilution to which the stomach contents may be subjected and still cause the ricin to disappear. The amount of gastric juice which is sufficient to clear up the 2 c.c. of a 2 per cent. ricin solution in three hours, kept at the blood temperature; is considered as 1 pepsin unit. The normal stomach contents contain about 100 pepsin units to the cubic centimetre.

RENNIN. Add 5 drops of the filtered gastric contents, preferably neutralized with deci-normal sodium hydroxide solution, to 10 c.c.

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of fresh neutral milk in a test-tube kept at 100° F. In about 5 to 15 minutes coagulation will occur if the rennin be normal. When no reaction is obtained within one-half hour rennin is absent. It has been demonstrated by Illoway that rennin may be present in nearly normal amount even if pepsin is entirely absent or markedly deficient. Rennin is usually the last one of the elements active in gastric digestion to disappear.

EXAMINATION OF STARCH DIGESTION. Ptyalin digestion continues in the stomach until the free hydrochloric acid reaches an appreciable amount.

Test for Carbohydrates.—A few drops of the filtered gastric fluid are placed on a porcelain dish and a drop or two of Lugol's solution added.

Starch turns the fluid blue; erythrodextrin, a reddish-purple; while achroodextrin only slightly discolors the solution. Maltose, which does not change the color, may be tested for by Fehling's test.

In normal digestion, sugar and achroodextrin are present, erythrodextrin absent or present in small amount and starch is absent. If a blue or a blue-violet color is obtained saccharification is deficient.

MICROSCOPIC EXAMINATION. The stomach contents are examined microscopically for food particles, for Boas-Oppler baccilli, for blood, and for evidences of foreign growths.

TEST FOR BLOOD.—If the microscope shows the absence of red corpuscles a chemical test should still be made. Ten c.c. of the gastric contents are placed in a test-tube and 3 c.c. of acetic acid are added. Add, then, 6 to 8 c.c. of ether, shake the mixture and pour off the etherial layer into another test-tube. Add 10 drops of recently prepared tincture of guaiac (1 in 60) then 30 drops of ozonized oil of turpentine; if blood be present a blue coloration will appear.

MOTOR FUNCTION OF THE STOMACH.

To test gross motor disturbances a combination of methods may be used. About eight o'clock in the evening the patient should eat a plate of porridge cooked with rice or raisins and one or two slices of bread and butter. The next morning before breakfast, or about twelve hours after eating, the stomach should be washed. A gross disturbance of the gastric motility is present if remnants

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of food are found, for instance raisins or rice which are easily recognized macroscopically. Such a condition is usually caused by some organic disturbance at the outlet of the stomach.

For all practical purposes the test dinner is all that is necessary. The one most usually given is the one divised by Riegel, which consists of a plate of soup, 150 grams of beef steak, a roll, a small-dish of potato puree, some stewed fruit and one glass of water. Seven hours after the meal the stomach should be washed. It will be found empty if the motility is normal. If remnants of food are present there is motor disturbance.

To test the motor function of the stomach, *chemically* administer to the patient, by capsule, 0.5 to 1.0 gramme of salol (phenyl salicylate). Test the urine after one hour and after 30 hours by the following method. Dip a strip of filter paper into the urine and then touch the moist paper with one drop of a 10 per cent. neutral solution of ferric chloride. A trace of salicylic acid will develop a violet-colored ring around the spot. With normal peristaltic movement the excretion of salicylic acid will begin about one hour after the administration of the salol, and will be completed within 30 hours.

To ascertain the *Rate of Absorption* administer to the patient a capsule containing 0.1 gramme of potassium iodide, and after some minutes test the saliva for iodine by the following method: Dip strips of filter paper into starch paste and dry. Moisten a strip of this paper with the patient's saliva, and then, with a glass rod, touch it with a drop of yellow nitric acid. The presence of iodine will be shown by the appearance of a blue spot. Normally the reaction will be obtained in from 10 to 15 minutes after the administration of the capsule.

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THE PANCREATIC FLUID.

NORMALLY, the secretion of the pancreas is a clear alkaline liquid with approximately the following percentage composition (Zawadsky): Water, 86.40 per cent.; solids, 13.59, of which 13.25, including 9.20 of proteid, is organic. In other analyses the total solids have varied between 2 and 15 per cent.

The ferments of the pancreatic fluid are three in number; trypsin, a proteolytic ferment, amylopsin, an amylolytic ferment, and steapsin, a steatolytic ferment. A fourth, a milk-curdling ferment, is sometimes mentioned, but can be of no importance. *Trypsin* resembles the pepsin of the gastric fluid, converting albumin into peptone; it differs from pepsin in that it acts best in an alkaline medium and carries the digestion further, with the production of leucin, tyrosin, aspartic acid, etc. *Amylopsin* acts upon starch, even when raw, converting it into maltose and dextrin with a trace of dextrose. It has no action on cane sugar. Glycogen is acted upon more slowly than starch. Amylopsin is comparable with, but is a more powerful ferment than, the ptyalin of the saliva. *Steapsin* splits fats into fatty acids and glycerol. The emulsifying action of the pancreatic fluid as a whole is, however, a more important factor in the preparation of fat for absorption.

An "artificial pancreatic juice" may be made by dissolving the dried pancreatic ferments in a one per cent. sodium carbonate solution. For the preparation of the ferments, a pancreas after standing for a day is minced and thoroughly extracted (several days) with glycerol. Alcohol is then added to the glycerol extract and the separated ferments are dried.

To demonstrate the digestive process place some of the alkaline ferment solution in four test-tubes. To one add a small piece of fibrin. The fibrin is gradually eroded, and dissolved, alkali-albumin, proteoses, and peptones are formed and may be recognized by the tests under proteins, page 125. By long-continued digestion leucin and tyrosin are also formed. To demonstrate the leucin,

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acidify the solution, boil, filter, add excess of absolute alcohol to the filtrate, again filter, and evaporate the last filtrate to a small bulk. Leucin is separated from the yellow fluid and may be recognized under the microscope or by other tests (see Index). The tyrosin may be tested for as follows: Precipitate the protein compounds with Millon's reagent, filter, and boil the filtrate. A red color indicates tyrosin. Or, test by adding to a reagent made up of formalin, 1 part; water, 45 parts; concentrated sulphuric acid, 55 parts. On boiling, if tyrosin be present, a green color is developed.

To the second tube add starch solution—maltose, dextrin and dextrose are formed. To the third tube add cane sugar—no change. Heat the fluid in the fourth tube to 60°C. and then cool. Divide this solution and test again with fibrin and with starch. No reaction is obtained in either case.

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THE BILE.

THE bile is a mixture of the secretions of the liver cells and of the mucous membrane of the biliary ducts and bladder. It is a golden-yellow, greenish, or brown, alkaline liquid with a specific gravity between 1.010 and 1.040. The lower specific gravity, with from 1.5 to 3.0 per cent. of solids, is characteristic of bile obtained from a fistula. Normally we have about 16.0 per cent. of solids, as follows (Hammarsten): Sodium glycocholate and taurocholate, 8.72; cholesterol, 0.87; lecithin, fatty acids, and fat, 1.35; mucin and pigment, 4.44; mineral salts, 0.54.

Glycocholic acid is present in the form of the sodium salt. On decomposition with acids, alkalies, or ferments, it yields glycocin and cholalic acid:

$$C_{26}H_{43}NO_6 + H_2O = CH_2NH_2COOH + C_{24}H_{40}O_5.$$

Taurocholic acid, $C_{26}H_{45}NO_7S$, also present as the sodium salt, on similar decomposition yields taurin, $C_2H_7NO_3S$, and cholalic acid. Other acids are also present, *e. g.*, fellic acid, $C_{28}H_{40}O_4$. The principal bile pigment is bilirubin, $C_{16}H_{18}N_2O_3$, golden-yellow, and from this by oxidation we get biliverdin, green, containing one more atom of oxygen in its molecule.

TEST FOR BILE ACIDS.

Pettenkoffer's Test. Add to the bile concentrated sulphuric acid and warm to about 60° C. Then add a ten per cent. cane-sugar solution, drop by drop, with constant stirring. A purple-red color turning to violet indicates the presence of bile acid.

The test is due to the decomposition of the bile acid, to the production of furfurol by action of the sulphuric acid on the sugar, and to the combination of this with the cholalic acid. The reaction is prevented or obscured by overheating and by excess of sugar. A similar reaction may be given by certain other substances, *e. g.;* oleic acid, amyl alcohol, and morphine. *See also, under Urine Analysis.*

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Tests for Bile Pigment.

Gmelin's Test. A drop of bile is spread in a thin film on a porcelain plate and a drop of yellow nitric acid added. In the presence of a bile pigment the drop of acid is surrounded by colored rings—green (biliverdin), blue (bilicyanin), and reddish-yellow (choletelin). Too much of the acid renders the succession of colors indistinct, and alcohol should be absent; proteins do not interfere.

Huppert's Test may be made as described under Urine Analysis, or, the moist precipitate, obtained on addition of lime water, may be placed in a test-tube half filled with acidified (sulphuric acid) alcohol and the mixture boiled for some time. If pigment be present an emerald-green color is developed.

In testing for bilirubin in blood, precipitate the protein matter with alcohol, filter, acidify the filtrate with sulphuric acid and boil; the liquid becomes green in color.

See also, under Urine Analysis.

Biliary Concretions.

"Gall stones" may consist of calcium salts with pigment, the so-called "pigment stones," or, more commonly, they are formed of cholesterol.

Cholesterol, $C_{27}H_{45}OH$, is found in varying amount in all the tissues of the body, especially in the brain and nerves, in semen, and in the excretions. It may be obtained in crystalline plates, insoluble in water, dilute acids or alkalies, soluble in boiling alcohol, in ether, chloroform, oils, and, slightly, in solutions of bile salts. It may be obtained from the concretion by crushing, boiling with water, and then with alcohol. On cooling the alcoholic solution cholesterol separates out in rhombic plates. This impure product is then boiled with alcoholic potassium hydroxide, the alcohol is evaporated, the residue extracted with ether, and the ether filtered and evaporated.

Salkowski's Test. Dissolve the cholesterol in chloroform and add an equal volume of concentrated sulphuric acid. The chloroform solution is violet-red, while the acid is dark red with a greenish fluorescence. As a micro-chemical test the cholesterol crystal touched with a drop of sulphuric acid shows colored rings, first carmine-red; then violet.

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THE INTESTINAL FLUID.

THE secretion of the intestinal glands, the glands of Lieberkuhn, is an alkaline fluid containing protein matter, sodium carbonate, and sodium chloride. Whether or not a digestive ferment is included, is still a matter of doubt, but it is probable that the intestinal fluid plays an important part in the inversion of the disaccharids, cane sugar, maltose, lactose, etc., into the monosaccharid dextrose, this inversion being attributed to the enzyme *invertin*. The secretion undoubtedly assists in the emulsifying of fats, and is of importance in the neutralization of the acids of fermentation.

More important, probably, is the decomposition of the undigested food residues by the *organized* ferments present in the intestinal tract.

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THE URINE.

Constituents of Normal Urine.—Urea and related substances, uric acid in the form of urates, xanthine, creatinine, etc. Compounds of fatty acids and minute traces of other non-nitrogenous substances, including carbohydrates. Aromatic substances; etherial sulphates of phenol, cresol, pyrocatechol, indoxyl and skatoxyl; hippuric acid in the form of hippurates, etc. Pigments and ferments. Mineral substances; chlorides, sulphates and phosphates of sodium, potassium, calcium and magnesium, ammonium compounds, and carbonates. Gases; nitrogen, carbon dioxide and traces of oxygen.

Abnormal Ingredients.—Serum-albumin and other proteins; blood and bile pigments, bile acids, abnormal urinary pigments; glucose, lactose, and glycuronic acid; acetone and diacetic acid; free uric acid; leucin and tyrosin; fats, lecithin, cholesterol, cystin; blood corpuscles, pus, casts, renal epithelium, etc.

A man weighing 65 kilogrammes will pass, in 24 hours, an average of 1480 c.c. of urine with a specific gravity of 1.020, the average amounts of the dissolved substances being about as follows: In a total of 60 grammes, solids, there will average—

Urea,	34.0 grammes.	Chlorine,	7.3 grammes.
Uric Acid,	0.6 "	Phosphorus Pentoxide,	3.0 "
Creatinine,	0.9 "	Sulphur Trioxide,	2.2 "
Hippuric Acid,	0.7 "	Potassium Oxide,	3.0 "
Other Organic Constituents,	2.3 "	Sodium Oxide,	4.5 "
		Calcium Oxide,	0.3 "
Total Organic,	38.5 grammes.	Magnesium Oxide,	0.4 "
		Other Inorganic Constituents,	0.8 "
		Total Inorganic,	21.5 grammes.

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CHEMICAL ANALYSIS OF THE URINE.

General Plan of Analysis.

I. Ascertain Quantity passed in 24 hours, and obtain an average sample.
II. Note Color, Appearance and Odor.
III. If turbid, estimate relative amount of Sediment and test character of same.
IV. Test Reaction with litmus paper.
V. Determine, the Specific Gravity.
VI. Calculate the Total Solids.
VII. Set aside a sample for Microscopic Examination; filter the remainder of the urine and use filtered urine for the following tests.
VIII. Test for Nucleo-albumin and Mucin.
IX. Test for Albumin, and, if present, determine amount. If more than a trace of albumin be present it should be removed before proceeding with the remainder of the tests.
X. Test for Sugar, and if present, determine the amount.
XI. Determine the amount of Urea.
XII. Determine the approximate amount of Chlorides.
XIII. Determine the approximate amount of Sulphates.
XIV. Determine the approximate amount of Phosphates.
XV. Test for "Indican."
XVI. Test for Acetone and for Diacetic Acid.
XVII. Test for Bile and for Blood.
XVIII. Make a Microscopic Examination of the Sediment.

Statement of Analysis.

All analytical data is computed on the basis of a twenty-four-hour sample, when possible; otherwise the results of the quantitative tests are calculated either to percentages or to amounts in 1000 cubic centimetres.

A regular form should be used in reporting results. The following is that used by one of the large city hospitals.

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ANALYSIS OF URINE.

NUMBER, NAME, WARD, BED, DATE.

PHYSICAL AND CHEMICAL EXAMINATION.

Appearance,	Albumin, Amount.
Bulk percent. of Sediment,	Nucleo-albumin,
Color,	Mucin.
Odor,	Sugar, Amount.
Reaction,	Acetone,
	Diacetic acid,
Specific Gravity at 25° C.,	Indican,
Quantity, 24 hours,	Bile,
Total Solids Calculated by Häser's coefficient,	Blood,
	Urea,
	Chlorides (Cl)
	Phosphates (P_2O_5)
	Sulphates (SO_3).

Remarks . . . . . .

Examination made by . . . . .

Checked by . . . . . .

MICROSCOPICAL EXAMINATION.

ORGANIZED SEDIMENT.

Casts	Epithelial,	Epithelium	Small Round,
	Narrow Hyaline,		Spindle,
	Broad Hyaline,		Pavement,
	Finely Granular,		Pus,
	Darkly Granular,		Blood,
	Blood,		Bacteria,
	Other Forms.		Other Products.

UNORGANIZED SEDIMENT.

Crystalline:	Amorphous:
Uric Acid,	Urates,
Calcium Oxalate,	Phosphates,
Triple Phosphate,	Other Forms.
Other Forms.	

Remarks . . . . . .

Examination made by . . . . .

Checked by . . . . . .

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Collection of Sample.

Owing to the variation in composition of the urine during the day the sample obtained for analysis should be an average of all passed. When possible the total urine voided in twenty-four hours should be collected, mixed, the total quantity measured and about eight ounces reserved for examination in a clean bottle.

It will be found convenient to begin the collection of the sample with the first urination after breakfast, collecting all the urine up to breakfast on the following day. If the average sample is not obtainable, note the time of passing—night, morning, before or after a meal, etc.

The sample should be analyzed as soon as possible after collection. The bottle in which the sample is placed should be full, tightly stoppered, and kept in a cool place. If the conditions are not favorable for the preservation of the sample, add a small piece of thymol, or better wash container with a saturated alcoholic solution of thymol and pour out excess so that a layer of small thymol crystals will form on the inner walls of the container. Camphor may also be used, but if chloroform or formaldehyde is added the ordinary tests for sugar become unreliable.

Quantity.

An adult man passes on an average 1200 to 1600 c.c. of urine in 24 hours (about 23 c.c. for each kilogramme of body weight).* Women secrete less than men; children absolutely less but relatively more (about 60 c.c. for each kilogramme of body weight). The amount varies, however, in all cases, with age, body weight, exercise, the emotions, conditions of temperature, etc. The urine is *increased* after the ingestion of much liquid, reaching 2000 to 3000 c.c. It is increased, also, in nervous excitement, hysteria, chorea, in forms of glycosuria, in chronic interstitial nephritis, and in amyloid kidney. It is *diminished* by profuse perspiration, hence in summer, by abstinence from liquid food, by sleep, often in valvular disease, acute inflammations, fever, diarrhœa, enteritis; in acute nephritis, in chronic parenchymatous nephritis, in uremia, in severe active hyperemia, and in passive hyperemia.

* The amount passed by thirty medical students varied from 1000 c.c. to 1625 c.c., the average amount being 1309 cubic centimeters.

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Color, Appearance and Odor.

Normal urine is described as clear, straw-yellow, sherry-colored, or amber. It varies normally in shade from nearly colorless to dark amber. The pigment has been variously designated but may best receive the non-committal name of Urochrome. A modification of the normal pigment occurs in disease and is known as febrile Urobilin; a normal Urobilin is also described, as well as a pigment, Uroerythrin, to which the uric acid and uric sediments owe their color. The urine is *light-colored* after ingestion of a large amount of water, in nervous conditions, and, generally, whenever the urine is greatly increased in amount; it is often nearly *colorless* in diabetes. It is *dark* after profuse perspiration, muscular activity, etc., and in acute febrile conditions. It may be *red*, *smoky*, or *brown* from presence of blood pigments, or *greenish-yellow*, *brown*, to *black* from presence of bile. "*Blue*" urine is sometimes observed in cholera and in typhus. Again, the color may be due to drugs ingested; phenol and gallic acid producing a *greenish-black* urine (carboluria); santonin, chrysophanic acid, rhubarb, senna, etc., an *orange* to *yellow* urine; sulphonal, a *dark-red* urine; methylene blue, a *blue* urine.

To accurately determine the color, a test-tube having a diameter of 20 mm. is filled with urine and comparison made with Vogel's color chart.

In case the color be so pronounced as to interfere with the chemical tests, the urine should be decolorized by shaking with powdered animal charcoal and filtering.

The urine is usually clear when passed, though a faint cloudiness is not uncommon. All urines become turbid on standing. A turbidity may be due to an excess of mucus, to pus, chyle, semen, phosphates, urates, etc. The *character of the sediment* may be roughly determined as follows: By heating, the turbidity due to *phosphates* is slightly increased, but it disappears at once on the addition of a few drops of nitric acid or of acetic acid. By heating, the turbidity due to *urates* disappears. If due to *pus*, the turbidity is generally increased by heat. A permanent red sediment is probably *uric acid*; this occurs in red grains in an acid, generally clear, urine is not soluble on warming, and is heavier than the urate deposit.

The Bulk Percentage of Sediment may be determined by filling a long graduated tube and noting the amount of sediment

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after 24 hours. 100 c.c. of normal urine will often yield 5 c.c. of sediment.

The *odor* of normal urine is described as *aromatic*. After standing, however, it may become *ammoniacal*. Asparagus, turpentine, cubebs, valerian, and garlic, all impart characteristic odors. The urine of diabetes has often a sweet odor, due generally to presence of acetone; that of albuminuria, after standing, a fetid odor. The urine of cystinuria has the odor of sweetbriar, but later becomes very offensive.

Reaction.

The reaction of an average sample of normal urine is always acid; the total acidity in terms of hydrochloric acid being 1.5–2.3 grammes for the 24 hours. The acidity is *reduced*, or the urine may become *alkaline*, after hearty meals, hot baths, administration of alkaline salts, etc., with a strictly vegetable diet, in general debility, chlorosis, and anemia. The acidity is *increased* with a meat diet, by muscular activity, in fevers, typhus, and often in pneumonia.

Upon standing the urine may at first become more acid, with decomposition of urates, but later an alkaline fermentation sets in, the urea is decomposed and ammonium carbonate formed.

$$CO(NH_2)_2+H_2O=(NH_4)_2CO_3.$$

At this stage the turbidity is increased by precipitation of phosphates, and an ammoniacal odor is noticeable.

Test the reaction of the urine with litmus paper. If an alkaline reaction be obtained (red litmus turns blue) dry and warm the paper. If the alkalinity be due to fixed alkalies the blue color will remain after warming and the alkalinity is referable to the blood. If the blue color disappears on warming, the alkaline reaction is due to the ammonium compounds formed in the urine by decomposition of the urea.

Total Acidity of the Urine. To 50 c.c. of urine add 1 c.c. of phenolphthalein solution and titrate with deci-normal sodium hydroxide until a permanent pink color appears. Each c.c. of the deci-normal alkali is equivalent to 0.003618 grammes of hydrochloric acid.

It is to be remembered that the acid reaction of the urine is in reality due to the presence of acid salts, NaH_2PO_4, etc., and not

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at all to the hydrochloric acid, this last substance being sometimes adopted, however, because of the greater ease in calculation and as affording a simple means of comparison.

Or the acidity may be reported in terms of deci-normal alkali, 50 c.c. of urine usually requiring from 20 to 40 c.c. of deci-normal alkali for neutralization.

In case the urine is highly colored, it is best first to remove the color by shaking with purified animal charcoal and filtering.

Specific Gravity.

The specific gravity of normal urine from adults varies generally between 1.010 and 1.030, with an average of 1.020 for 1500 c.c. passed.* In children from two to thirteen years of age the average is about 1.012.

In order that the determination of the specific gravity shall be of value, it is necessary to know the amount passed and to use an average sample.†

Considered with the amount passed in 24 hours, the specific gravity gives the following indications: A *decreased amount* with *increased specific gravity* indicates diminished secretion, loss of water by other excretions, or the presence of some morbid process, acute nephritis, fever, etc. An *increased amount* with *decreased specific gravity* indicates abundant ingestion of water, absorption of exudations, or some form of diseased kidney, *e. g.*, interstitial

* The specific gravity of the urine from thirty medical students varied from 1.012 to 1.030, with an average of 1.016.

† When the amount passed varies from the normal (1500 c.c.) the specific gravity of the average sample may be reduced to the normal by the formula:

$$\frac{A \times G}{1500} + 1000 = D.$$

In which A equals the amount passed, G equals the second and third decimals of the observed specific gravity, and D equals the specific gravity of the urine reduced to the normal quantity. Thus, suppose 3000 c.c. were passed, and the specific gravity of the average sample to be 1.015.

$$\frac{3000 \times 15}{1500} + 1000 = 1.030.$$

Reduced to the normal, then, of 1500 c.c., the specific gravity is 1.030, showing that while the specific gravity of the original sample was low, the total solids are in reality high.

Note, however, that in calculations, *e. g.*, in calculating the total solids, the observed, not the revised, specific gravity must be used.

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nephritis. A *decreased amount* with *decreased specific gravity* indicates, possibly, uremia, or chronic parenchymatous nephritis. An *increased amount* with *increased specific gravity* may indicate diabetes mellitus.

The specific gravity is usually determined by means of the urinometer, a small hydrometer with special scale. This scale is adjusted to give accurate readings at a certain temperature (usually 60° F.) marked upon the instrument, and as the temperature of the urine tested is nearly always above this, it is necessary, in accurate determinations, to make a corresponding correction. The temperature of the urine is determined and for each 6° above 60° F., *one thousandth* is added to the observed specific gravity. Thus the corrected specific gravity for a urine reading 1.020 at 72° F. is 1.022.

It is advisable to always take the specific gravity at the same temperature, usually 25° C. (77° F.). This may easily be done by warming or cooling the sample as required.

For more accurate determinations it is necessary to use the pycnometer, for which, see works on physics.

Total Solids.

The solids in the normal urine of 24 hours vary from 45–65 grammes, with an average for the male adult of about 60 grammes (926 grains). In practice, however, age, sex, diet and exercise must be considered, and a proper figure adopted for each case under observation. For differences in age, deduct one-tenth for each ten years after forty. For light diet or for fasting, deduct from one-tenth to one-third. For confinement to bed, deduct one-tenth; for confinement to the house, deduct one-twentieth.

The solids may be calculated with sufficient accuracy for clinical purposes by multiplying the integers in the second and third decimal places of the specific gravity by Häser's coefficient, 2.33. The product gives the number of grammes in 1000 c.c. of the urine, and from this the number of grammes in the urine passed may be easily calculated. Other factors, or coefficients, which have been proposed are Trapp's = 2, and that of Loebisch = 2.2. Häser's coefficient is that most often used, though probably the coefficient of Loebisch, or the even simpler one of Trapp, will give nearer to the true amount of total solids. For the urine of young children, the coefficient 1.80 should be used.

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It is to be remembered that these methods of calculation are based upon the study of normal urines. They can not be used when the urine is grossly pathological.

If more accurate results are required a weighed sample must be carefully evaporated to dryness at a low temperature, preferably in a vacuum.

Nucleo-Albumin and Mucin.

Nucleo-albumin and mucin are present in minute traces in normal urines, the mucin partially in solution and partially as a faint cloud or *nubecula*. In irritation of the urinary tract these substances are generally considerably increased in amount, and should be tested for early in the analysis, as a failure to recognize their presence may lead to an erroneous interpretation of the tests for the more important serum-albumin. Both nucleo-albumin and mucin are precipitated by addition of acetic acid in the cold, unlike albumin, and, unlike albumin, too, they are not coagulated by boiling. In the heat test for albumin, however, the addition of acetic acid may cause a precipitation of mucin.

Mucin Test.—To the urine in a test-tube add an equal volume of water, filter if necessary, and then add strong acetic acid, drop by drop. In the presence of mucin a precipitate is formed, *soluble in excess* of the acid. Urines of low specific gravity may be tested without previous dilution, using in such cases, however, a diluted acetic acid.

Nucleo-Albumin Test.—To 5 c.c. of the urine add an equal amount of a saturated solution of sodium chloride and then, slowly, 5 c.c. of Almen's tannin solution, the latter consisting of a solution of 5 grammes of tannin, dissolved in 10 c.c. of 25 per cent. acetic acid, with 250 c.c. of 40–45 per cent. methyl alcohol. A precipitate is formed if nucleo-albumin be present.

For *Mucus*, see under Urinary Sediments.

Albumin (Serum-Albumin).

Normal urine is practically free from proteins, but on the other hand the presence of a trace of albumin is not necessarily always of serious import. Temporary albuminuria may occur after severe bodily exertion, after the shock of a cold bath, from excess of albuminous foods, from the presence of semen, etc. When more than a trace is present, or when this trace persists for a consider-

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able time, the existence of a serious abnormal condition is indicated. Serum-albumin and serum-globulin are the forms of protein most frequently met with, while hemoglobin, fibrinogen, peptones and proteoses may also appear. In general, the immediate cause of albumin in the urine may be stated as impaired circulation through the glomeruli of the kidney, the result of either venous or arterial disturbance, changes in the blood itself, or diseased condition of the kidney. The albuminuria of pregnancy, like that due to ovarian or uterine tumors, is generally a result of disordered venous reflux, and the same may be said of the albuminuria of heart disease. Albumin may occur in gout, in scarlet fever, diphtheria, pneumonia, and as a result of irritant poisoning. It is typical in Bright's disease. In acute parenchymatous nephritis there is considerable albumin and often blood, the urine is decreased and the specific gravity is high. In chronic parenchymatous nephritis there is considerable albumin, the urine is normal or decreased, and the specific gravity is generally low. In chronic interstitial nephritis the urine is increased, the specific gravity is low, and the albumin is small in amount. In amyloid degeneration the urine is increased, the specific gravity is low, and there is considerable albumin. In acute interstitial nephritis both the amount of urine and the specific gravity are decreased, while the albumin is variable.

Among other diseases giving rise to albuminuria may be mentioned cystic disease of the kidney, acute and passive renal hyperemia, renal tuberculosis, calculus, uremia, hydronephrosis and pyonephrosis.

The urine must be filtered before making tests for albumin.

HEAT TEST. A long test-tube is three-quarters filled with clear, filtered, acid urine, and the upper half of this is carefully heated to boiling. A cloudiness appearing in the heated portion may be due to albumin or to phosphates. Add a few drops of 25 per cent. nitric acid; phosphates will be dissolved and any cloudiness remaining will be due to albumin.

Precautions.—If the urine is not already acid, acidify, before heating, by the addition of a few drops of dilute nitric acid. Acetic acid may be used, but has the double disadvantage of being more likely to cause the solution of a trace of albumin than nitric, and, also, of precipitating mucin. A cloudiness appearing only after cooling may be due to albumoses. Urates, if abundant, some-

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time separate on cooling, but are not likely to be mistaken for albumin. The addition of nitric acid after boiling should be continued until one drop has been added for each c.c. of urine.

Nitric Acid Contact Test. (Heller's Test.) Place some pure nitric acid in a test-tube, and float over it carefully, by means of a pipette, an equal volume of the urine to be tested. A white zone or ring at the contact of the two liquids indicates albumin.

Instead of pure nitric acid, in this test, Roberts' solution, a mixture of 1 part concentrated nitric acid and 5 parts saturated solution of magnesium sulphate, may be used.

Precautions.—A pink, red, or brown color may appear at the contact, due to the action of the acid on the chromogens of the urine. When cold acid is used in the test, crystalline nitrate of urea may separate at the contact, or acid urates may cause a cloudiness just above. Resinous matters, if present, as after ingestion of turpentine, balsams, etc., may cause a yellowish-white zone, which is, unlike albumin, however, in being soluble in alcohol. Albumose is precipitated by nitric acid in the cold, dissolves on heating, and reappears on cooling.

Ferrocyanide Test. To a little acetic acid in a test-tube add 2–3 volumes of potassium ferrocyanide, and then add the urine. The presence of albumin is shown by a milky turbidity or flocculent precipitate. Purdy claims that this test is given by albumin and its modifications, but not by other urinary ingredients. Experience, however, will demonstrate that, while alkaloids and peptones do not precipitate, urates, albumoses, and nucleo-albumin may.

Picric Acid Test. Warm some picric acid solution in a test-tube and add the urine to it, drop by drop. A slight opalescence as each drop of urine enters the acid indicates albumin. This test may also be performed by the contact method, floating the acid over the urine.

Precaution.—If cold acid be used, peptones, albumose, mucin, and alkaloids may also be precipitated. With the warm acid the test is exceedingly delicate, mucin, or nucleo-proteid, alone interfering. The alkaloidal precipitation is especially liable to occur after large doses of quinine. In a highly acid urine picric acid may cause the separation of urates, and sometimes of uric acid.

Carbol-Glycerin Test. To 2 c.c. of a mixture of equal parts liquid carbolic acid and glycerin add 2 c.c. of filtered urine, and mix by shaking. A turbidity indicates albumin.

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For other tests, Tanret's, etc., see Albumins, p. 128.

QUANTITATIVE ESTIMATION. The quantitative estimation of albumin is difficult, and an accurate determination is rarely possible in the ordinary clinical analysis. A rough comparison of the amount of albumin in the urine from day to day may be had from the bulk of coagulum obtained by heating, using always the same size tube and the same amount of urine.

The amount may also be roughly determined from the heat test, heating all of the urine in the tube, as follows :

If after boiling and allowing to stand for several hours a very slight turbidity is seen, about 0.01 per cent. albumin is indicated; 0.05 per cent. will produce an appreciable sediment; 0.1 per cent. will give a sediment occupying about one-tenth of the urine column; 0.25 per cent., one-fourth; 0.50 per cent., one-third; 1.00 per cent., one-half; while with 2–3 per cent. albumin the entire column will coagulate.

A more accurate estimation may be made with *Esbach's Albuminometer*. The urine, diluted with a known volume of water if there be much albumin, is introduced into the tube to the mark U, and Esbach's reagent (see Appendix) added to the mark R. The reagent is mixed with the urine, by inverting twelve times but not by shaking, the tube stoppered and allowed to stand 24 hours. The volume of the precipitate measured by the graduations, gives the percentage of albumin by weight, each main division representing 0.1 per cent. There is rarely more than 1.0 per cent. of albumin present.

If the approximate amount of albumin present is desired quickly, take 5 c.c. of *Tsuchiya's Reagent* (phosphotungstic acid 1.5 Gm., hydrochloric acid 5 c.c., alcohol to 100 c.c.) in a test-tube and add the filtered urine from a burette until a permanent turbidity is seen after shaking. The amount of urine used will contain 0.0001 Gm. of albumin.

Another fairly satisfactory method is the following: The urine is diluted with 9 volumes of water, and from this diluted urine (one-tenth urine) test solutions are prepared, each containing 10 c.c. of water and a measured volume of the one-tenth urine; *e. g.*, (1) Contains 10 c.c. of water plus 1 c.c. of the one-tenth urine; (2) Contains 10 c.c. of water plus 2 c.c. of the one-tenth urine, etc. Nitric acid contact tests are now made with each test solution until one is found which responds only after standing for 2–3

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minutes. The percentage of albumin in the original urine may be calculated from the formula:

$$\frac{10 + V}{30\ V} = P.$$

In which V equals the volume of one-tenth urine added to the 10 c.c. of water, and P equals the percentage sought. For example, if to the test solution, which produces a zone of coagulum only after standing 2–3 minutes, 5 c.c. of the one-tenth urine had been added, then the percentage of albumin originally present is

$$\frac{10 + 5}{30 \times 5} = 0.10 \text{ per cent.}$$

Heller's Nitric Acid Contact Test may be made roughly quantitative by accurately observing the following details:

Half fill a small round-bottomed wine glass with the filtered urine. Incline the glass slightly and slowly pour down the side concentrated nitric acid (sp. gr. 1.42) until the glass is three-quarters filled by the two liquids. A sharp zone of contact must separate the acid layer from the urine. Allow to stand undisturbed for exactly ten minutes, and then examine before a window and report results according to the following:

1. If no white zone can be detected unless a black background be held at a slight angle behind one-half of the glass, and then the zone is just discernible, report—slightest possible trace. This corresponds to about $\frac{1}{6}\frac{1}{0}$ of 1 per cent. of albumin.

2. If a faint white zone can be distinctly seen with the black background, report—slight trace. This corresponds to about $\frac{1}{4}\frac{1}{0}$ of 1 per cent. albumin.

3. If a distinct white zone is observable without the aid of a black background, and if when looking down through this zone the bottom of the glass is easily seen, report—a trace. This corresponds to about $\frac{1}{2}\frac{1}{0}$ of 1 per cent. albumin.

4. If a distinct white zone is formed, and if, when looking downward, the bottom of the glass is only dimly seen, report—large trace found. This corresponds to about $\frac{1}{1}\frac{1}{0}$ of 1 per cent. albumin.

In case the white zone is granular or very prominent, the amount of albumin must be estimated by *Esbach's* or *Tsuchiya's* methods.

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Serum-Globulin, Albumose and Peptone.

Clinically, *globulin* has much the same significance as has albumin. It is often associated with albumin, generally in smaller, but sometimes in greater amount, and, indeed, it may occasionally be the only protein present. Globulin is generally abundant in acute inflammations of the kidney. The *albumoses* occur rather constantly in osteomalacia and in other bone diseases, and less constantly in a variety of widely differing pathological conditions, notably after severe exertion, in ulcerative and suppurative conditions and during the stage of resolution in pneumonias. *Peptones* have been generally confused with albumoses in urinary literature, and their true significance in the urine is, therefore, doubtful. Their most interesting occurrence is in association with pus formation.

Serum-Globulin.—This responds to most of the albumin tests, but is insoluble in water and may be detected by dropping the urine slowly into a beaker of clear water, each drop as it falls producing a slight cloud. To separate globulins and albumins, saturate the urine (which preferably has been previously exactly neutralized with sodium hydroxide) with magnesium sulphate; the globulins are precipitated and can be filtered off. The filtrate may be tested for albumin by acidifying with acetic acid and boiling.

Albumose.—Tested for in presence of other proteins, as follows: Saturate the urine with sodium chloride, acidify with acetic acid, boil, and filter while hot. The albumose separates from the filtrate on cooling; dissolve in water and apply the nitric acid test. Albumose precipitated by nitric acid, dissolves on heating, and is reprecipitated on cooling.

Peptone.—In presence of other proteins, acidify faintly with acetic acid, saturate with ammonium sulphate, best at the boiling temperature, filter and examine the filtrate by the picric acid test—precipitation in the cold. The biuret reaction, which is generally the best test for peptones, cannot here be used.

Removal of Albumin from the Urine.

Albumin, if present in more than a trace, should be removed before proceeding with the remainder of the analysis. Acidify faintly with acetic acid and heat to boiling; watch the formation of the coagulum, and, at the instant it becomes distinctly flocculent, remove the source of heat, and filter.

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When the urine is to be used for quantitative tests, take a measured volume, and, after boiling and filtering, make up to the original volume with water.

Sugar in Urine.

Transitory glycosuria may occur in cerebro-spinal meningitis, in epilepsy, from brain injuries, under the influence of strong emotion, in pneumonia, ague, gout, in cholera, in disease of the pancreas, and after excessive use of saccharine food. Lactose is frequently present in the urine of mothers during the weaning period. Cane sugar may appear after ingestion of large quantities of that carbohydrate. *Permanent glycosuria* is generally considered to be indicative of diabetes mellitus. In general, diabetic urine is pale straw-colored, with sometimes a greenish tint; it is often turbid, and may have a sweetish odor. The specific gravity is generally high (1.030–1.050) and the quantity passed is seldom less than 1600 c.c. in 24 hours. It may vary, however, between the extreme limits of 500 c.c. and 8000 c.c. Diabetes mellitus with polyuria is far more serious than without, and, indeed, glycosuria without polyuria does not seem to be necessarily mortal. The percentage of sugar usually varies from 2 to 6 per cent., but may reach 12 per cent.

Trommer's Test. Add to the urine in a test-tube about one-fourth its volume of sodium hydroxide, and then dilute copper sulphate, drop by drop, until a slight permanent precipitate is formed, or until a dark-blue solution is obtained. In the presence of glucose the bluish-white precipitate of cupric hydroxide first formed dissolves on agitation, producing a dark-blue solution. Heat the liquid, and, in the presence of glucose, yellow cuprous hydroxide and red cuprous oxide are precipitated just as the liquid begins to boil. The same precipitation takes place without heating, but much more slowly.

Precautions.—A normal urine sometimes, and a fever urine generally, may decolorize the solution, but without the formation of the characteristic red precipitate. The sodium hydroxide causes a precipitation of flocculent phosphates, which, however, bear no resemblance to the granular cuprous precipitate. A precipitate of yellow cuprous hydroxide, which separates on the cooling of the test, may not be due to sugar. Uric acid, hippuric acid, creatinine, xanthine bases and mucin may cause a partial reduction of

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the copper solution. Glycuronic acid produces a complete reduction. The presence of albumin, peptones, etc., interferes with the delicacy of the test. When there is but a slight reduction, greater accuracy may be attained by clarifying the urine with animal charcoal or lead acetate, filtering and testing the filtrate.

FEHLING'S TEST. Dilute the Fehling's solution (see Appendix) with three volumes of water, heat to boiling—the solution should remain perfectly clear—and then, to the hot solution, add the urine drop by drop. A yellowish-red precipitate, as in Trommer's test, indicates glucose.

Precautions.—See under Trommer's test.

HAINES' TEST. Four or five c.c. of Haines' Solution (see Appendix) are heated to boiling in a test-tube and 8 drops of the urine slowly added. A yellowish-red precipitate, as in Trommer's test, indicates glucose.

Precautions.—See under Trommer's test.

BÖTTGER'S BISMUTH TEST. To a few c.c. of the urine in a test-tube, add an equal volume of sodium hydroxide and a few grains of bismuth subnitrate. Mix well and boil for several minutes. In presence of glucose, black metallic bismuth will be precipitated. A rather more delicate reaction is obtained by using the ALMEN-BÖTTGER'S TEST (Nylander's). Ten c.c. of urine are boiled with 1 c.c. of Almen-Nylander's reagent (see Appendix); black metallic bismuth is separated.

Precautions.—Albumin, if present, will cause the precipitation of black bismuth sulphide. Many normal urines will cause a slight darkening of the bismuth subnitrate, such as might be produced by a trace of sugar.

PHENYLHYDRAZINE TEST. To 50 c.c. of urine add 2 grammes of phenylhydrazine hydrochloride, and 4 grammes of sodium acetate. Dissolve the reagents in the urine and heat on the water-bath for one hour. In presence of glucose, fine yellow crystalline needles of glucosazone separate out on cooling.

This test is important because it does not depend upon the reducing properties of the sugar, but on the formation of a definite chemical compound.

For clinical purposes the test may be modified as follows: To 5 drops of the *liquid* phenylhydrazine add 10 drops of glacial acetic acid and 1 c.c. of a saturated sodium chloride solution. Shake well, and add 3 c.c. of urine. Heat at boiling temperature

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for two minutes and then cool slowly. In presence of more than 0.5 per cent. glucose, crystals of glucosazone will form within two minutes. Examine under the microscope.

Precautions.—A similar precipitate is given by other carbohydrates, and under certain circumstances by glycuronic acid. The precipitate should be examined microscopically for the characteristic crystals, and it may be even necessary to determine their melting-point (204°–205° C.) in order to positively identify them.

FERMENTATION TEST. (See page 117). This test is useful in identifying glucose in presence of other reducing substances, as, for instance, in distinguishing glucose in presence of glycuronic acid. It is not, however, to be relied upon when but a small amount of glucose is present and may be prevented entirely by the presence of antiseptics, mercuric salts, quinine, salicylic acid, after iodoform, etc.

QUANTITATIVE DETERMINATION. *By Fehling's Solution.*—Ten c.c. of Fehling's solution (see Appendix) are measured into a 100 c.c. flask with 40 c.c. of water. The diluted solution is heated to boiling and the urine added from a burette until the blue color of the Fehling's solution has entirely disappeared. Note the number of c.c. of urine required to produce this result, and calculate the amount of glucose present, by the formula $\frac{5}{U} = P$, in which U represents the number of c.c. of urine added to produce complete decomposition, and P equals the percentage of glucose in the sample.* From this the amount passed in the 24 hours can be calculated. When considerable sugar is present, it is well to dilute the urine with a known volume of water, to determine the glucose in the diluted sample, and then to calculate back to the original.

Several trials may be necessary before the proper amount of urine to add is determined; and often it is advisable to first add the urine in two cubic centimeter portions, making later trials more accurately after the approximate amount has thus been learned.

Hold the surface of the liquid on the level of the eye when examining for the last traces of the blue color. By adding barium sulphate (Stanislaus' method) the precipitated copper oxides will be caused to settle more rapidly.

* Ten c.c. of Fehling's solution are reduced by 0.05 grammes of glucose; therefore the percentage of sugar present $= \frac{0.05}{U} \times 100$.

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By Purdy's Ammoniacal Copper Solution.—Dilute the urine with two or three volumes of water carefully measured. Place 35 c.c. of the test solution (see Appendix) in a 200 c.c. flask, add about 70 c.c. of water, boil, and, from a burette, add the diluted urine until the blue color of the solution is just destroyed. The 35 c.c. of Purdy's solution are decolorized by 0.02 gramme of glucose. From the number of c.c. of urine required to produce the result, calculate the amount of glucose present, first in the diluted and then in the undiluted urine.

Pavy's ammoniacal copper test is very similar to Purdy's, and is sufficiently described in the Appendix. Purdy's method is a highly satisfactory one for clinical purposes, though, in skilled hands, Fehling's is unsurpassed. The *Fermentation Methods* which follow, are recommended especially when reducing substances other than glucose are known to be present. The results have only a clinical accuracy.

By Loss in Density after Fermentation.—Two specimens of urine are put aside; the one, in a bottle with perforated stopper, has added to it a small piece of compressed yeast, the other, without yeast, in a tightly-stoppered bottle. The two specimens are left for 12–24 hours at a temperature of 80° F., and then their specific gravities are determined. The difference in specific gravity (water being 1000) multiplied by 0.2196 gives the percentage of sugar. Stearn's apparatus is convenient in applying the test.

Einhorn's Method.—Ten c.c. of the urine are shaken with about 1 gramme of compressed yeast, and the mixture introduced into Einhorn's apparatus, a small graduated tube of special form. The carbonic anhydride gas evolved is measured at the end of 24 hours, its volume expressing directly, by the graduations on the tube, the percentage of glucose present. It will be noticed that the maximum graduation of the Einhorn tube is one per cent. If the urine contains more than one per cent. of sugar it will, then, be necessary to dilute with a measured volume of water before making the test.

By the Polariscope.—The quickest, and also, generally, the most accurate method for determining the amount of dextrose in urine is by means of the polariscope, measuring the amount of optical rotation caused by the solution. The cost of the instrument required, however, makes this test unavailable in the ordinary clinical laboratory.

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Urea, $CO(NH_2)_2$.

The urea varies in normal urine from 20 to 40 grammes (309 to 617 grains) in the 24 hours, with an average for men of about 34 grammes* (535 grains). It is to be noted that this average is for an adult male under forty years of age and in good health. Age, sex and conditions must be considered in deciding upon a normal average for each individual under examination. For variations from normal conditions deductions may be made in the proportions given under the total solids, page 165. Women secrete less than men, children absolutely less, but relatively, *i. e.*, in proportion to body weight, more. The urea is *increased* by a nitrogenous diet at the beginning of the crisis in fevers, in ague, in diabetes, in pleurisy, and in acute tuberculosis. The urea is *decreased* by profuse perspiration, by diarrhœa, in cholera, in all forms of Bright's disease, in diabetic coma, in anemia, and, generally, in most chronic debilitating disorders. Expressing, as it does, the progress of nitrogenous metabolism in the body, the determination of the urea passed is important.

Hypobromite Method.—There are several applications of this method, depending on differences in the form of apparatus used; the principle is the same, however, in all. A *fresh* solution of sodium hypobromite containing an excess of sodium hydroxide (see Appendix) is added to the urine; the urea is decomposed, nitrogen gas is set free, and sodium bromide and carbonate are formed.

$$CO(NH_2)_2+3NaBrO+2NaOH = 3NaBr+Na_2CO_3+N_2+3H_2O.$$

The nitrogen evolved is measured and, from its volume, the percentage of urea is calculated.

Twenty c.c. of fresh solution of sodium hypobromite (40 c.c. of the chlorinated soda) are placed in a bottle, and the measured urine contained in a small test-tube is introduced in such a manner that the tube will stand in the bottle without spilling. The bottle is connected by means of a perforated stopper and rubber tube, with the top of an inverted burette standing in a jar of water. All connections are carefully made, and the volume of air in the burette read from the graduations. The urine is now slowly mixed with the hypobromite, nitrogen gas is evolved, and a correspond-

* The urea reported by thirty medical students varied from 13.2 Gm. to 45.5 Gm. in twenty-four hours. The average was 29.1 Gm.

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Prep. sol 1 125 g. $NaNO_3$
125 g. $BaCl_2$

Sol No 2. 22½ g. NaCl

Take 10 cc. of each & dil. each with 30 cc. dist. H_2O; set aside one minute with 1 cc. of mixture.

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ing volume of air is driven from the bottle, displacing the water in the burette. When the evolution of gas has ceased, let the apparatus stand for a few minutes, and then measure again the air in the burette. The increase in volume represents the volume of nitrogen given off. The observed increase, in c.c., multiplied by the factor 0.0027, gives the weight in grammes of urea in the sample taken; *e. g.*, if 4 c.c. of urine were used for the test, and 21 c.c. of nitrogen were evolved, then we have $0.0027 \times 21 = 0.0567$ gramme of urea in 4 c.c. of urine, or, 1.42 per cent. $(0.0567 \div 4 \times 100)$.

When reading the volume of gas in the burette it is, of course, necessary that the latter shall be raised or lowered, so as to bring the water on the same level inside and out.

The *Ureameter* devised by Prof. Doremus, is convenient, and in its latest form, with a side tube for accurate delivery of the urine replacing the pipette formerly used, it yields excellent results. The long arm of the instrument is nearly filled with the alkaline solution of sodium hypobromite, water is added to cut off the elbow leading from the bulb, and then one c.c. of urine is carefully introduced at the foot of the long arm. The percentage of urea is read directly from the graduations on the tube.

When results of greater accuracy are required the urea present is either decomposed in an autoclave or it is determined by Folin's method.

Uric Acid, $H_2C_5H_2N_4O_3$, and Urates.

Uric acid, averaging from 0.3 to 0.8 grammes in the 24 hours, is normally present in combination as a urate. It is *increased* in pneumonia, indigestion, acute rheumatism, in leucocythemia, by excessive meat diet, by lack of exercise, and in disorders of the circulation and respiration. It is *decreased* in most chronic diseases, in the later stages of Bright's disease, in gouty affections, and in chronic rheumatism. It is to be remembered that the appearance of a deposit of uric acid, or of urates, does not necessarily point to an excess of these ingredients. High acidity of the urine, and a decrease in mineral salts, tend to produce a separation of uric acid equally with the presence of an increase of that substance. A heavy sediment of urates is common in fever urines. The deposits are easily recognized. (See under Urinary Sediments.)

Uric acid may be separated from the urine as follows: To 200 c.c. of urine add 20 c.c. of strong hydrochloric acid and let the

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mixture stand 48 hours. Collect the sediment on a previously weighed filter paper, wash with cold water, dry and weigh. The increase in weight represents uric acid.

To detect uric acid or urates apply the *Murexid Test.* Evaporate the sediment with a drop of nitric acid. A yellow residue is obtained, which, when moistened with a drop of ammonium hydroxide, turns to a purple-red.

Determination of Uric Acid—Hopkins' Method.—Saturate the urine with crystalline ammonium chloride, filter off the precipitated ammonium urate, wash with a saturated solution of ammonium chloride, dissolve in weak alkali, neutralize with hydrochloric acid, and collect the uric acid on a weighed filter.

Modified Hopkins' Method.—Saturate 100 c.c. of urine with ammonium chloride, and let the mixture stand in a cool place over night. Filter and wash the precipitate with ammonium sulphate solution until free from chlorine, and then, having perforated the filter, with a jet of hot water wash the precipitate into a flask. Add about 100 c.c. of pure concentrated sulphuric acid, and titrate at once with twentieth-normal potassium permanganate until a faint pink tinge persists for a few seconds throughout the liquid. One c.c. of twentieth-normal potassium permanganate equals 0.00375 gramme of uric acid. *Preparation of the Reagent.*—Dissolve 1.577 grammes of potassium permanganate in 900 c.c. of water, and titrate into 10 c.c. of hot (60° C.) deci-normal oxalic acid which has been previously acidified with dilute sulphuric acid. The exact strength of the permanganate having been determined, dilute the remainder until 20 c.c. exactly neutralize 10 c.c. of the deci-normal oxalic.

Chlorides.

The chlorine of the 24 hours' urine varies from 6 to 10 grammes, equivalent to 10 to 16 grammes of sodium chloride. The average for an adult man may be placed at 7 grammes chlorine* (11.5 grammes sodium chloride), for women, at 6 grammes chlorine, and for children, about 5 grammes chlorine. The amount varies during the day, being *increased* several hours after a full meal. It is *diminished*, in most fevers (increasing again just before or just after the crisis), in diseases associated with serous exudation (in-

*The chlorine voided by thirty medical students averaged 6.968 grammes in twenty-four hours.

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creasing again with absorption of the exudate), in pneumonia, pleurisy, acute meningitis, and, to a less extent, in typhoid, and in many chronic diseases.

Approximate Estimation.—To the urine in a test-tube add a few drops of dilute nitric acid and 2–3 drops of a 10 per cent. solution of silver nitrate. If the chlorides be high or normal, a curdy white precipitate is formed; if low, only a milky cloudiness.

Accurate Determination.—The general method for chlorides (p. 88) may be applied to the urine, using a 10 c.c. sample and diluting with water. Subtract one (because of substances precipitated other than chlorides) from the number of c.c. of deci-normal silver nitrate used and multiply the remainder by 0.003518. The result will be the weight of chlorine in the sample, and from this the percentage may be calculated. Should it be desirable to report in terms of sodium chloride, multiply by 0.005806 instead of by 0.003518. In the application of this test to the urine there are, however, unavoidable errors, and the following—*Volhard's Method*, is preferred. The solutions required in addition to the deci-normal silver nitrate, are ferric-ammonium sulphate (ferric-alum) 10 grammes dissolved in 100 c.c. of water; and deci-normal potassium sulphocyanate solution—Dissolve 10 grammes of potassium sulphocyanate in one liter of water. Introduce into a flask 10 c.c. of deci-normal silver nitrate, 0.5 c.c. of ferric-alum solution and 5 c.c. dilute nitric acid. Add the sulphocyanate from a burette until there is produced a faint brownish-red color, which does not disappear on shaking. Note the number of c.c. of sulphocyanate used, and then dilute the remainder until one c.c. is exactly equivalent to one c.c. of deci-normal silver nitrate.

The process of analysis is then as follows: In a 150 c.c. flask place 3.518 grammes (about 3.4 c.c.) of urine, 3 c.c. nitric acid, and 20 c c. water. Add 10 c.c. deci-normal silver nitrate, exactly measured, and shake the mixture. Add 0.5 c.c. ferric-alum solution, and then, from a burette, the deci-normal sulphocyanate until the appearance of a faint, permanent, brownish-red coloration indicates the end of the reaction. Subtracting the number of c.c. of potassium sulphocyanate added from the 10 c.c. of silver nitrate used, we ascertain the amount of silver nitrate required to precipitate the chlorides of the sample. Each c.c. so required represents 0.10 per cent. of chlorine in the urine.

For sodium chloride, multiply the chlorine found, by 1.65, or,

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modify the above test, using 5.806 grammes (about 5.7 c.c.) of urine and 15 c.c. of silver nitrate. Each c.c. of deci-normal silver nitrate then required for the precipitation corresponds to 0.10 per cent. of sodium chloride.

Volhard's method may also be applied as follows:—To 10 c.c. of urine in a beaker add 40 c.c. of distilled water, then 3 c.c. of nitric acid free from nitrous compounds, 3 c.c. of saturated solution of ferric-ammonium alum, and 30 c.c. of deci-normal silver nitrate.

Determine the amount of silver nitrate in excess of that needed to precipitate all of the chlorides, by adding deci-normal potassium sulphocyanate until a permanent change of color is seen in the liquid. Subtract the number of c.c. of deci-normal sulphocyanate used from 30 (the number of c.c. of deci-normal silver nitrate taken) and multiply by 0.003518. The result will be the number of grammes of chlorine in the 10 c.c. of urine. Multiplying by 0.005806 instead of by 0.003518 will give the chlorine in terms of sodium chloride.

Sulphates.

Sulphuric acid is found in the urine combined with both organic and inorganic bases, the latter combination being normally in excess of the former. Calculated to sulphur trioxide, the sulphates vary in normal urine from 1.5 to 3 grammes daily, with an average of about 2.2 grammes. The sulphates are *increased* by animal food, by ingestion of sulphur compounds, in acute inflammatory diseases, pneumonia, acute rheumatism, delirium, and often in diabetes insipidus. They are *decreased*, with diminished metabolism, in chronic affections, in leucemia, and in diabetes mellitus.

After large doses of salol, lysol, etc., and in carbolic acid poisoning, the ordinary sulphates are greatly decreased, and may be absent. There is, however, at the same time a corresponding increase in the sulphates of organic bases.

Approximate Estimation.—Add to the urine a few drops of dilute hydrochloric acid and one-fourth volume of barium chloride. An opaque milky cloudiness indicates normal sulphates; an opaque creamy precipitate, increased sulphates; a faint semi-transparent cloudiness, diminished sulphates.

Sulphates of Organic Bases. Sulphates of phenol, cresol, pyrocatechol, indol, skatol, etc. These compounds are derived partially from the food, but are interesting chiefly as putrefaction

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Estimation of albumen by centrifuge m
If urine is cloudy, filter.
Fill grad. centrif. tube to 10 c.c. mark
acid. methyl orange (0.1%), and add
strong liq. NH3 from dropper
and mix well. Add
then to mark. Centrifuge
Read only ½ c.c. of ppt. by lower,
Each ½ c.c. = to 13/100 % Na Cl
by weight.

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products absorbed from the small intestine. In normal urine they are present in small amount, averaging about 10 per cent. of the total sulphates, but in certain stomach troubles, in disordered absorption, and from abnormal fermentative and putrefactive changes, as well as in carbolic acid poisoning, etc., they may be considerably increased.

Determination of Organic Sulphates.—100 c.c. of the urine are mixed with 100 c.c. of barium mixture (see Appendix), and the precipitate formed filtered off. An aliquot part of the filtrate is acidified with hydrochloric acid and boiled. It is then heated to 100° C. for an hour, allowed to stand until completely settled, and finally filtered through an ashless paper. The precipitate is dried, ignited and weighed. The weight of barium sulphate found, multiplied by 0.34291, gives its equivalent in terms of sulphuric anhydride.

Total Sulphates (Folins' Method).—To 50 c.c. of urine in an Erlenmeyer flask add 0.2 gramme of pure potassium chlorate and 4 c.c. of hydrochloric acid. Boil gently, and when the urine is clear add 25 c.c. of barium chloride solution (60 grammes to the litre). Maintain at a temperature near boiling for 45 minutes, filter, and wash thoroughly with hot water and with hot 5 per cent. solution of ammonium chloride, using not less than 100 c.c. of the latter and 500 c.c. of the former. Fold the paper, pour upon it 2 or 3 c.c. of strong alcohol, place in a crucible, burn the alcohol, ignite and weigh the residue.

Phosphates.

The phosphates of the urine may be divided into two classes, the *alkaline phosphates*, phosphates of sodium and potassium ($\frac{2}{3}$); the *earthy phosphates*, phosphates of calcium and magnesium ($\frac{1}{3}$). The *total phosphates* calculated as phosphorus pentoxide, vary in normal urine from 2.5 to 3.5 grammes, with a daily average of 3 grammes. They are *increased* in acute inflammatory diseases, in the early stages of acute fevers, in phthisis, leucemia, osteomalacia, destructive pulmonary diseases, in over-active metabolism, by a diet rich in nuclein, in some nerve and mental disorders, in some forms of indigestion, and in phosphatic diabetes. They are *decreased* in many chronic diseases with lowered metabolism, in epilepsy, general paralysis, etc., in chronic interstitial nephritis, in chlorosis, gout, and chronic rheumatism.

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In acid urines the phosphates of calcium and magnesium occur as acid phosphates, but as the urine becomes less acid or alkaline, normal phosphates are formed and may be precipitated. When a urine only faintly acid is heated a similar precipitate often forms. This precipitate is readily soluble in a few drops of nitric acid (difference from albumin).

Total Phosphates.—Add to the urine magnesia mixture (see Appendix) and ammonium hydroxide. The total phosphates are precipitated, and can be compared with a corresponding precipitate from a normal urine.

Earthy Phosphates—Approximate Estimation.—Place 2 inches of urine in a 6-inch test-tube, add a few drops of sodium hydroxide and heat to boiling. Set aside for 15 minutes to allow the precipitate to settle. If the phosphates be normal the precipitate will occupy about ½ inch at the bottom of the tube; if high, 1 inch or more; if low, less than ¼ inch.

Alkaline Phosphates—Approximate Estimation.—Add a little ammonium hydroxide to the urine, filter off the precipitated earthy phosphates, and to the filtrate add ⅓ volume of magnesia mixture. compare the precipitate obtained with one from a normal urine.

Determination of Total Phosphates—Solutions.—Standard Uranium Nitrate:—Dissolve 35.5 grammes of uranium nitrate in a mixture of 25 c.c. strong acetic acid with 800 c.c. of water. Dilute with water to 1000 c.c. Each c.c. of this solution is equivalent to 0.005 gramme of phosphoric anhydride, P_2O_5.

Acid Solution of Sodium Acetate:—Dissolve 10 grammes of sodium acetate in 90 c.c. of water and add 10 c.c. of strong acetic acid.

Potassium Ferrocyanide:—One gramme dissolved in 120 c.c. of water.

Method.—To 50 c.c. of urine add about 10 c.c. of the sodium acetate solution and warm the mixture to 80° C. Maintain at this temperature, and, from a burette, add the standard uranium nitrate, testing from time to time until a drop of the mixture develops a brown color when touched with a drop of potassium ferrocyanide. The number of c.c. of uranium nitrate used, multiplied by 0.005, gives the weight in grammes of phosphoric anhydride in the 50 c.c. of urine.

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Indican.

Indican, or, properly, potassium indoxyl-sulphate, $C_8H_6NKSO_4$, is derived from the indole, C_8H_7N, of the intestine. Normally present in small amount, it becomes greatly increased in certain intestinal disorders from absorption of decomposition products from the small intestine. It is increased generally in cancer of the liver, in certain suppurative diseases, by intestinal obstruction, by peritonitis, and by the administration of many aromatic drugs, creosote, turpentine, etc.

Test:—To 10 c.c. *concentrated* hydrochloric acid add 20–30 drops of urine, mix with the upper half of the acid, and let stand for 10–20 minutes; a yellow or very pale violet represents normal, a darker violet, increased indican.

Jaffé's Test:—To 10 c.c. of urine add 10 c.c. of concentrated hydrochloric acid and then, with constant shaking, a perfectly fresh saturated and filtered solution of calcium hypochlorite until the color ceases to darken. Shake with 2 c.c. of chloroform, which dissolves the indigo, and, after the liquids separate, judge the amount of indican by the depth of color of the chloroform layer.

Bile.

Bile constituents may appear occasionally in the urine of healthy persons, particularly during the heat of summer, but as a rule their presence is characteristic of the condition known as jaundice. Bile pigment and bile acids may both be present, but the clinical examination is practically limited to the former. The urine is generally yellowish-brown to green, sometimes almost black, and yields a characteristic yellow froth on shaking. It must be remembered, however, that certain drugs may produce a similar appearance.

Tests for Bile Pigments. *Marechal's Test.*—Float a few drops of a dilute solution of iodine on the surface of the urine in a test-tube. In the presence of bile pigments, a green coloration appears below the red iodine layer.

Gmelin's Test.—The urine is floated over yellow nitric acid in a test-tube. A succession of colors, green, blue, violet and red, will appear at the contact of the two liquids.

In Rosenbach's modification of this test the urine is filtered through a thick paper. A drop of yellow nitric acid applied to the inside of the dried filter will produce a yellow spot surrounded by yellowish-red, violet, blue and green rings.

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Fleischl's Test.—Add sodium nitrate to the urine and then float it over strong sulphuric acid. The same colors are obtained as in Gmelin's Test.

Huppert's Test.— The urine is treated with lime water, or with a solution of calcium chloride followed by ammonium carbonate; the precipitate is filtered off, thoroughly washed, and then transfered to a test-tube. A little acetic acid is now added, then chloroform. On shaking, the acetic acid will be colored green, while the chloroform will show a yellow or green tint according to the relative amounts of bilirubin and biliverdin present.

TEST FOR BILE ACIDS. *Pettenkofer's Test.*—Evaporate about 200 c.c. of urine to dryness, extract the residue with absolute alcohol, filter, evaporate the alcoholic filtrate, and dissolve the second residue in a little water. Add a few drops of a concentrated solution of cane sugar and a drop of sulphuric acid, then warm the mixture in a capsule. A purple or cherry-red color indicates the presence of the bile acids.

Instead of evaporating the alcoholic filtrate the bile acids may be precipitated from that solution by an excess of ether, the precipitate separated, and dissolved in water. The water solution in either case will probably need to be decolorized by animal charcoal before applying the color test.

The test may be *clinically modified* as follows: To the urine, which must be albumin-free, add a little sugar syrup and then dip into the mixture a strip of filter paper. Dry the paper and touch it with a drop of sulphuric acid. Bile acids being present, a purple spot *may* be obtained.

Or, a second modification.—Dissolve some cane sugar in the urine and warm a thin film of the mixture on a flat porcelain dish. Dip a glass rod in strong sulphuric acid and draw it across the film —its track is marked by a purplish line.

For other modifications of the bile tests, see p. 155.

BLOOD.

BLOOD in the urine may be derived from the kidneys, in cancer, acute nephritis, after powerful diuretics, etc.; from the bladder, in diphtheritic and acute cystitis, calculi, carcinoma, congestion, etc.; from structural disease of the prostate, and from mechanical injury. When uniformly mixed with the urine the blood is probably from the kidneys, though possibly from the prostate; when

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stringy or in clots, it is more likely to be from the bladder or urethra. When the blood appears only in the first urine passed it is probably from the urethra or from the prostatic region. Unless in considerable amount, its recognition is best effected by microscopic examination of the sediment or by spectrum analysis. As regards the microscopic examination, however, it is to be remembered that blood pigment may be present when blood corpuscles are entirely absent (Hemoglobinuria). When the amount of blood is large the urine will be dark-red or brown, often "smoky" in appearance. and the precipitate of earthy phosphates with sodium hydroxide (*Heller's test for blood*) will be reddish instead of white. Should the urine be alkaline and the phosphates already precipitated, add an equal volume of normal acid urine and a few drops of barium chloride before boiling with sodium hydroxide. Hemoglobin may be detected by the *Guaiacum Test.*—To the urine in a test-tube add 3–4 drops of a freshly prepared tincture of guaiacum and mix by shaking. Float on the surface of the mixture a little etherial solution of hydrogen dioxide ("ozonic ether") and let it stand without shaking. In presence of hemoglobin (and of some other substances) a blue color well develop at the contact between the two liquids. After ingestion of potassium iodide a greenish color may be obtained.

Lecanau's Test may be used for the detection of hematin. The urine is acidulated with acetic acid and boiled. The brown coagulum is separated, washed with water, and shaken with alcohol which has been acidulated with sulphuric acid. The reddish-brown solution is filtered and the filtrate examined spectroscopically. A part of the same filtrate may be evaporated to dryness and the residue tested for iron.

Hemin Test.—Place a few drops of the urine on a glass slide and add a drop or so of glacial acetic acid.* Heat cautiously until bubbles appear. On cooling there will separate out dark brown triclinic plates and prisms of "hemin," the hydrochloride of hematin.

Benzidin Test.—Shake 4 c.c. of ether with 10 c.c. of urine and 1 c.c. of acetic acid. Remove the clear supernatant etherial liquid with a pipette after it has separated and transfer it to a clean test-tube containing a mixture of ½ c.c. freshly saturated aqueous solu-

* In testing non-saline solutions it is necessary to add here, also, a small crystal of sodium chloride.

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tion of benzidin 2 c.c. of glacial acetic acid and 2 c.c. of hydrogen dioxide. A blue or green color will be formed in two minutes and, in five minutes, a dirty purple.*

Other Abnormal Ingredients.

Acetone, $(CH_3)_2CO$, normally present in minute amount, is increased in febrile conditions, in the later stages of diabetes mellitus, in starvation, in gastric cancer, and, frequently, after profound narcosis. It may be tested for in the urine directly, or better after distillation of the urine with phosphoric acid. A few cubic centimetres may be distilled in a few minutes from a small retort. *Legal's Test.* To 5 c.c. of the urine (or to the distillate) add sufficient sodium hydroxide to give a decided alkaline reaction, and then add a few drops of a fresh aqueous solution of sodium nitroprusside. The mixture assumes a ruby-red color. Acidify the solution with glacial acetic acid; a purple-red color indicates the presence of acetone. This test serves, also, as a test for *Creatinine*, for when this substance is present in considerable amount a dark grass-green coloration is obtained on addition of the acetic acid. *Gunning's Iodoform Test.* To 5 c.c. of urine or to 2 c.c. of distillate add a few drops of Lugol's solution. A slowly forming yellow crystalline precipitate having the characteristic odor and microscopic appearance of iodoform, indicates acetone. Should the crystals not form well, recrystallize from ether and examine again.

Acetylacetic Acid, $CH_3CO.CH_2COOH$, commonly called *Diacetic Acid*, or its ethyl-ether compound, is related to acetone in its occurrence, and is, possibly, an intermediate step in the formation of acetone. Its appearance in the urine of a diabetic is to be considered of grave import. Diacetic acid may be tested for as follows: To the *fresh* urine add a few drops of a neutral solution of ferric chloride. Filter off any precipitated phosphate, and to the filtrate add two drops more of the iron salt. A Bordeaux-red color being produced, diacetic acid may be present. Repeat the test, using a boiled portion of the urine; little or no color will now be developed if the color of the first test were due to the acid and not to salicylates or related substances. As a further test a portion of the urine

*This test is said to detect 1 part of blood in 300.000, but may give positive results with other substances—$CuSO_4$, $KMnO_4$, pus and ferments. If a positive test is obtained results should be confirmed with turpentine guaiac mixture or spectroscopically. A negative test is good evidence of the absence of blood.

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is acidulated with sulphuric acid and extracted with ether. Apply the iron test to the ethereal extract. If the color produced fades in 24–48 hours, it is probably due to diacetic acid; if it does not fade, it may be due to oxybutyric acid. *Arnold's Test.*—Two solutions are required, one a 1 per cent. solution of sodium nitrite, and the other a solution of paramidoacetophenone. The latter is prepared as follows: Dissolve 1 gram of paramidoacetophenone in 80–100 c.c. of water, shake to effect solution, and add hydrochloric acid drop by drop, until the liquid is clear, and the yellow color is destroyed.

For the test, mix 2 c.c. of paramidoacetophenone solution with 1 c.c. of the sodium nitrite, add 3 c.c. of urine, and 2 or 3 drops of strong ammonium hydroxide; a brownish-red color is obtained with all urines. To 2 c.c. of this mixture add 20 c.c. of concentrated hydrochloric acid, and, if acetylacetic acid be present, a purple-violet color will be obtained, otherwise, in absence of acetylacetic acid, a yellow. This test is not given by acetone nor by oxybutyric acid.

Oxybutyric Acid, $CH_3CHOH.CH_2COOH$, is closely related to acetone and diacetic acid, and often occurs with them in the urine. It is found in the later stage of diabetes as a result of abnormal katabolism, in cachexia, also sometimes in scarlet fever, measles, etc. It responds to the ferric chloride test for diacetic acid.

Glycuronic Acid, $CHO.(CH.OH)_4COOH$— closely related to dextrose. Occurs in combination in normal urine in traces, but is much increased by ingestion of chloral, benzene, turpentine, phenol, resorcinol, thymol, menthol, nitrobenzene, camphor, morphine, etc., and particularly after a profound chloroform narcosis. It is of importance because of its resemblance to glucose, responding to several of the principle glucose tests. It does not, however, respond to the fermentation test with yeast, and, unless present in large amount, gives no reaction with phenylhydrazine, provided this test be performed exactly as described on page 173. With insufficient heating of the mixture crystals are obtained, melting at 150° C.

In common with *pentose*, glycuronic acid gives the following test: Decolorize the urine with charcoal and add 0.5 c.c. to 5 or 6 c.c. of a saturated solution of phloroglucin in strong hydrochloric acid. Upon warming, a purple-red color is developed.

Pentoses, ($C_5H_{10}O_5$) have been found in urine in several cases but at present their clinical significance is not known.

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Pus.—Pus in the urine (pyuria) may be from renal abscess, from inflammation or cancer of the bladder, from suppuration in the prostate or urethra, etc. When the pus originates in the bladder the urine is generally alkaline in chronic inflammations and acid in acute inflammations; when from the kidneys, the urine is generally acid. Pus from the urethra is best recognized by the "2-glass test." Pus is easily recognized microscopically, but, if in considerable amount, the following tests may be applied: The whitish sediment always present in urine carrying pus is not dissolved by heat. It is insoluble in dilute acids, and—*Donné's Test*—with sodium hydroxide it forms a semi-gelatinous, ropy mass. A similar change takes place during the alkaline fermentation of a urine carrying pus. Hydrogen dioxide added to pus causes a rapid effervescence.

Fat.—May be due to an excess of fatty food, or it may occur in fatty degeneration of the liver, in phosphorus poisoning, etc., occasionally in diabetes mellitus, after fractures of the long bones, and in Bright's disease. When the fat is present in considerable amount (lipuria) the urine will be more or less milky in appearance, and, on standing, the fat globules will rise to the surface. The fat may be extracted from such a sample by agitation with ether. When present in small amount the fat globules, or fatty casts, will be recognized in the microscopic examination.

In *chyluria* all of the chyle constituents, fat, proteins, etc., are present. *Cholesterol* has been found in chyluria, and, also, in fatty degeneration of the liver and, sometimes, in diabetes, and in jaundice.

Drugs, Alkaloids, etc.—In irritant poisoning the urine often contains albumin and blood. In phenol poisoning, and after ingestion of phenol derivatives, the urine is dark-colored and may become black on exposure to the air. Indican seems to be increased in the urine by the ingestion of oil of bitter almonds, turpentine, and creosote. After the ingestion of balsams a test may be obtained with nitric acid resembling that given by albumin. Santonin, chrysophanic acid, rhubarb and senna, give an orange-yellow color. Asparagus, turpentine, cubebs, and valerian all impart characteristic odors. Salicylates are excreted as salicylic and salicyluric acids. Glycuronic acid is increased by chloral, nitrobenzene, camphor, and morphine, and after chloroform narcosis. The ingestion of potassium iodide causes the urine to give

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a greenish-blue coloration in the guaiacum test for blood. Quinine and antipyrine darken the urine, the latter giving a reddish tint, and the former giving a precipitate with picric acid. Quinine, atropine, strychnine, morphine, and other alkaloids may be excreted in part unchanged. Sulphonal and trional may produce a dark red urine, the color being due to hematoporphyrin. Methylene blue gives a blue urine.

Iodides and iodoform are tested for by adding a little dilute starch paste and then a few drops of yellow nitric acid; a blue color indicates presence of iodine.

To test for lead in the urine, evaporate repeatedly with strong nitric acid until the organic matter is destroyed. Dissolve the residue in water, evaporate, again dissolve in water, and test for lead with potassium iodide, etc., according to tests p. 30.

Arsenic and other metals may be tested for in a similar manner after destruction of the organic matter, either with nitric acid, as described above, or according to the Fresenius-Babo Method, page 80.

EHRLICH'S DIAZO-REACTION.

Two solutions are prepared, one a saturated solution of sulphanilic acid in 50 c.c. of hydrochloric acid, diluted to 1000 c.c. with water; the other a 0.5 per cent. solution of sodium nitrite.

In applying the test one part of the nitrite solution is added to 50 parts of the sulphanilic acid solution, and then one volume of this mixture is added slowly to an equal volume of urine. Ammonium hydroxide is added in slight excess and the tube is well shaken. A carmine-red color appearing in the foam, as well as in the body of the liquid, constitutes the diazo-reaction. Normal urine shows an orange coloration.

This reaction is given generally by the urine of typhoid fever patients from the 4th to the 7th day, continuing, possibly, to the 22d day. It is given also, though later, in miliary tuberculosis, often in carcinoma and in septicemia, occasionally in scarlet fever and erysipelas, and, very rarely, in other acute febrile diseases. In phthisis pulmonalis a persistent reaction is of grave significance. In miliary tuberculosis the reaction is not obtained until the third week, and, therefore, it may serve to differentiate this disease from typhoid fever.

It is interesting and important to note that phenol derivatives, creosote, creosotal, etc., interfere with the Ehrlich's reaction.

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URINARY SEDIMENTS.

Urinary sediments may be divided into two groups, organized or anatomical, unorganized or chemical. The anatomical sediments include mucus and pus cells, blood corpuscles, epithelium, casts, spermatozoa, fungi, etc. The chemical sediments vary with the reaction of the urine, *acid urine* containing amorphous and semi-crystalline urates of sodium and potassium, crystalline uric acid, calcium oxalate, and, rarely, crystalline calcium acid phosphate, cystin, leucin and tyrosin; while *alkaline urine* may contain amorphous phosphate and carbonate of calcium, crystalline ammonium urate, ammonium-magnesium phosphate, phosphates of calcium and magnesium, and calcium oxalate.

The sediment is separated from the urine by deposition, or, better, by use of the centrifuge. When the examination is to be delayed it is necessary to guard against fermentative changes, and for this purpose a little powdered camphor, salicylate of sodium, 10 grains to 4 ounces of urine, thymol, formaldehyde, 1–2 drops to 4 ounces of urine, or chloral hydrate may be added.

Chemical Examination of the Sediment.

Warmed with water—Soluble; Urates (and hippurates, normal calcium urate only slightly, leucin, tyrosin and xanthine slightly). *Insoluble;* Phosphates, oxalates, uric acid (cystin, cholesterol and, possibly, leucin, tyrosin and xanthine).

Add acetic acid—Soluble; Phosphates and carbonates, the latter with effervescence. (Leucin and tyrosin, and xanthine slightly.) *Insoluble;* Oxalates, uric acid (hippuric acid, cystin, cholesterol, sulphates and, possibly, tyrosin).

Add hydrochloric acid—Soluble; Oxalates, phosphates, and carbonates (effervescence). (Urates and hippurates dissolve but decompose with separation of uric and hippuric acids; leucin, tyrosin, cystin dissolve; sulphates partially dissolve.) *Insoluble;* Uric acid (also hippuric acid and cholesterol, the latter soluble in ether).

Add sodium hydroxide—Soluble; Uric acid (leucin, tyrosin, cystin, xanthine and bilirubin crystals). *Insoluble;* Oxalates, phosphates, carbonates (sulphates and cholesterol). (Earthy phosphates are precipitated from solution.)

As regards the effects of the above reagents on the possible organic contents: *heat* may coagulate albumin; *acetic acid* may pre-

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cipitate mucin and may dissolve casts, etc.; *hydrochloric acid* may precipitate albumin and may destroy casts, etc.; sodium hydroxide may dissolve mucus to a clear solution, and may convert pus into a thick, viscous mass. Micro-organisms are dissolved by sodium hydroxide and are also evidenced by a milkiness in the urine, not removable by ordinary filtration.

Anatomical Sediments.

Mucus Cells.—Often present in normal urine. Round or oval globules with faintly marked margins, averaging about 0.01 mm. in diameter, but sometimes swelling to twice that size, generally with but a single nucleus. Mucus in excess appears in the urine as a flocculent, amorphous cloud, easily soluble in sodium hydroxide. (See also, p. 166.)

Pus Cells.—From suppuration in the urinary tract. Similar to mucus cells in appearance, but distinguished by being generally multinuclear, the indistinct nuclei being rendered more prominent by addition of acetic acid. The pus cells are distinguished from white blood corpuscles by their somewhat larger size, their granular appearance and their more irregular outlines. The addition of alkalies converts pus into a gelatinous mass. Urine carrying pus generally yields albumin by chemical tests. (See also, p. 188).

Blood Corpuscles.—Recognized as more or less yellow biconcave discs with smooth or crenated margins, generally without nuclei. In dilute urine the corpuscle is often swollen, and occasionally is biconvex in form. In concentrated urine shrunken and crenated corpuscles are common.

Epithelium. — Occurs in rounded, cylindrical, polygonal, or granular, nucleated cells. These may originate in the bladder, ureters, pelvis of the kidney, kidney, urethra, or vagina. The large, flat "squamous" cells from the vagina and bladder are common in the urine of women. Renal epithelial cells are rounded or polygonal, small, and often with a large nucleus. Certain of the smaller round cells may resemble pus, but their single nucleus and greater size will easily distinguish them. Epithelium is much increased by catarrh in the urinary tract.

Casts.—Moulds of the uriniferous tubules of the kidney, pointing to a diseased condition of that organ, inflammation, congestion, etc. Classed, according to appearance, as hyaline casts, waxy casts, epithelial casts, blood, fatty, and granular casts. They are, in

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general, cylindrical in shape, with rounded ends, often nearly transparent and difficult to identify. They are best detected after staining with a dilute solution of iodine with potassium iodide or with magenta, and by use of concentrated light. They are quickly destroyed by the fermentation of the urine. Casts are found in acute and chronic nephritis, in jaundice, etc. Hyaline casts may occur in all forms of albuminuria, in fever urine, and in many chronic disorders, though when few in number and when the patient is past middle life their presence is not incompatible with a fairly normal health. As the disease or inflammation progresses, granular, epithelial and blood casts become more numerous. Fatty casts indicate a fatty degeneration. Blood casts indicate a renal hemorrhage. The presence of casts together with pus and blood generally suggests the renal origin of the latter.

Fungi, Bacteria, etc.—Absent from normal urine when passed, but often developing rapidly on exposure to the air. Yeast fungi are often abundant in diabetic urine. The micrococcus ureæ, derived from the atmosphere, multiplies rapidly in urine, and is the chief factor in the ammoniacal fermentation.

Bacteria may be examined for as follows: A little of the sediment is spread on a cover-glass, dried, and passed quickly through a Bunsen flame, to fix the layer. Stain for fifteen minutes in warm carbol-fuchsin (fuchsin, 1 part, dissolved in absolute alcohol 10 parts, and 5 per cent. phenol 100 parts added), and then dip for several seconds in 25 per cent. sulphuric acid. Wash with water, and stain with methylene blue (concentrated alcoholic solution of methylene blue 30 parts, 0.01 per cent. potassium hydroxide 100 parts). Wash again with water, dry, and mount in balsam. Tubercle bacilli appear red, all others will be stained blue.

For *Gonococci* spread the sediment on a cover-glass and fix by heat as described above. Then cover the deposit with a few drops of ordinary methylene blue or violet solution. Wash in water, place on a slide and examine at once in water or in glycerol, or, dry and mount in balsam. The more or less kidney-shaped gonococci are found generally in pairs united by their flattened surfaces. The presence of the gonococci within the pus cells is particularly significant.

Spermatozoa are often present, and may occasionally prove to be of medico-legal interest. Their characteristic form is easily recognizable under a high power.

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Chemical Sediments.

Uric Acid.—Common in acute fevers, uric acid diathesis, gravel, etc. Found in acid urine in red or brownish-yellow crystals. The crystals, which are described as whetstone, envelope, spear and fan-shaped, are often gathered together in bundles or in rosettes. They are insoluble in acids, but are dissolved by alkalies, and, slowly, by heat. The murexid test (p. 178) may be applied.

Urates.—In acid urine, associated with uric acid, we find sodium and potassium acid urates. In alkaline urine we find crystalline or amorphous ammonium urates. The urates are generally amorphous, or in a state of semi-crystallization in the form of balls studded with spicules. Crystalline forms are somewhat more common in alkaline than in acid urine. The murexid test (p. 178) may be applied. Urates are generally easily soluble on warming. They are soluble in acids with decomposition and with ultimate precipitation of uric acid.

Oxalates.—Calcium oxalate occurs in the urine in small octahedra or in envelope and dumb-bell forms. Its presence is not always significant, being frequently derived directly from the food, but it may point to mal-assimilation, and is often associated with an increase in uric acid. A large or constant excretion of calcium oxalate (Oxaluria) may be considered a serious condition.

Phosphates.—Crystalline di-calcic phosphate may occur (rarely) in acid urine. In alkaline urine we may have amorphous phosphates of calcium and magnesium, crystalline tri-magnesic phosphate (rare), crystalline di-calcic phosphate in rosettes, spherules, or dumb-bells, ammonium-magnesium phosphate, "triple phosphate," in large bevel-edged prisms, or, occasionally, in stellate feathery forms. When present in freshly-voided urine, the triple phosphate indicates decomposition of the urine in the bladder. The presence of other crystalline phosphates and of amorphous phosphates is not particularly significant.

Carbonates.—Rare as a sediment. Amorphous calcium carbonate may occur in alkaline urines, occasionally in imperfect dumb-bell forms, but generally as rounded or oval granules with dark contours, soluble in acetic acid with effervescence.

Leucin.—A rare sediment, occasionally appearing in white shiny lamellæ, generally, however, in groups of yellowish striated spherules, sometimes like those of sodium urate, but distinguished

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from the latter by not dissolving on application of heat. They are distinguished from oil-drops by their insolubility in ether. Leucin is soluble in mineral acids and in alkalies, and slightly soluble in acetic acid and in hot water.

Tyrosin.—A rare sediment, occurring with leucin in acute atrophy of the liver, in small-pox and in typhus. It is usually found in the form of yellowish-green globules, but when pure occurs in fine needle-like crystals radiating from a center. Tyrosin is soluble in mineral acids and in alkalies, and slightly soluble in acetic acid and in hot water.

Cystin.—A rare sediment, found, in acid urine only, in colorless six-sided transparent plates, often in overlapping masses. The crystals are soluble in hydrochloric acid and in ammonium hydroxide, but are insoluble in water, and insoluble in acetic acid and in ether. The solution of cystin in ammonium hydroxide on evaporation gives the characteristic crystals. A trace of sodium nitroprusside added to an alkaline solution of cystin develops a violet color. Boiled with a drop of lead acetate, cystin causes the separation of black lead sulphide. Cystin is of interest chiefly because of its tendency to formation of calculi.

Other rare sediments are calcium sulphate, hippuric acid and hippurates, cholesterol, xanthine, fat globules, and bilirubin crystals. For the behavior of these and the other sediments with chemical reagents, see page 190.

URINARY CALCULI.

Calculi may consist of uric acid and urates, of calcium oxalate, ammonium oxalate, and, more rarely, of phosphates, carbonates, cystin, xanthine, etc. As a rule each calculus is built up of two or more of the above substances arranged in concentric layers around a central nucleus. These layers may often be separated, and in analysis should be examined separately.

Uric Acid and Urates form hard calculi, generally smooth, often reddish or yellowish-brown in color, and of variable size. Pure *Phosphatic Calculi* are of rare occurrence, though we frequently find phosphates deposited around a uric acid nucleus. The *Fusible Calculus* consists of a mixture of calcium, magnesium, and ammonium phosphates. It is readily fusible when heated, giving off vapor of water and ammonia. It resembles chalk in appearance and consistency. *Calcium Oxalate* is frequently met with, forming

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calculi often of considerable size, brown or olive in color (*mulberry calculi*). When small and hard, the term *hemp-seed calculus* is applied. The rare *Cystin Calculi* are more or less transparent and waxy in appearance, though crystalline in structure. They are commonly tinted yellow, changing to green on exposure. *Xanthine Calculi* are very rare. They are described as yellowish-brown in color, often with scattered white spots. Occasionally altered blood clots will form concretionary masses known as *Fibrinous Calculi.*

The following scheme will serve as an aid in the recognition of the chief varieties of calculi:

Powder the calculus and heat a small portion of the powder on platinum foil in the Bunsen flame.

A. If it chars, burns, and leaves but little residue, it probably consists of either *uric acid*, *urates*, *cystin*, *xanthine* or *fibrin.* Test a portion of the powder with boiling water; if soluble, we have *urates;* if insoluble, *uric acid.* Confirm in either case by the murexid test.

Treat another portion of the powder with hydrochloric acid, and warm; a residue may be *uric acid;* cystin and xanthine go into solution. *Cystin* gives a brown color with the murexid test and is soluble in ammonium hydroxide. The ammonium solution on evaporation yields the characteristic hexagonal crystals. For other tests see p. 194. *Xanthine* gives a yellow color with the murexid test, but if potassium hydroxide be used instead of ammonium hydroxide, it turns red, and, on heating, reddish-violet. *Fibrinous calculi* will be completely burned when heated, giving off the characteristic odor of burning feathers.

B. Should the powder, when heated, char but slightly and leave a considerable residue, or, possibly, undergo no change at all, we may have *phosphates*, *oxalates*, or *carbonates*, of calcium and magnesium.

A fresh portion of the powder is treated with dilute hydrochloric acid; if soluble with effervescence, *carbonates* are present; if soluble without effervescence, we have phosphates or oxalates. A residue will probably consist of uric acid. Filter, render alkaline with ammonium hydroxide, boil, acidify with acetic acid, and again filter. A white pulverulent residue is *calcium oxalate*, which, if dried and heated on platinum, is converted into calcium carbonate, soluble in hydrochloric acid with effervescence.

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To the filtrate from the calcium oxalate add ammonium hydroxide; a white precipitate indicates calcium or magnesium *phosphate*. To demonstrate the presence of phosphates, and of calcium, and magnesium, separately, to a portion of the above filtrate from the calcium oxalate add neutral ferric chloride—a precipitate = *phosphates*. To the rest of the filtrate add ammonium oxalate. Filter off the precipitated *calcium* oxalate, and to the filtrate add a little sodium phosphate and ammonium hydroxide. If *magnesium* be present it is slowly precipitated in the form of ammonium-magnesium phosphate.

C. Should the powder when heated melt and give off water-vapor with fumes of ammonia, the calculus consists of a mixture of calcium, magnesium, and ammonium phosphates. (The Fusible Calculus.)

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THE PERSPIRATORY FLUID.

THE sweat or perspiratory fluid generally contains in suspension epithelial cells and fat globules, but when filtered it is a clear, colorless liquid with salty taste and characteristic odor. The reaction is frequently acid, possibly from presence of fatty acids from the sebum, but profuse sweat is generally neutral or alkaline. The specific gravity is about 1.005 and the total solids about 1.5 per cent. In normal sweat we find neutral fats, volatile fatty acids, cholesterol, traces of proteins, creatinine, urea, aromatic oxyacids, etherial sulphates, sodium and potassium chlorides, sulphates and phosphates. Ammonium carbonate is generally present as a result of urea decomposition; albumin is increased in the acid sweat of acute rheumatism; dextrose appears in diabetes; urates, and oxalates, in gout; urea is increased in uremia; lactic acid appears in puerperal fever, bile pigments in jaundice. Drugs and ingested poisons frequently appear unchanged in the sweat, and may there be detected.

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THE FECES.

THE fecal discharge from the body consists of rejected food residues, products of the mucous and other intestinal glands, the remains of the digestive fluids and of the bile, bacterial products, gases, etc. The amount of water varies usually from 70–85 per cent.

In health the *Amount* of evacuation for twenty-four hours varies from 50–400 grammes, with an average of 150 grammes, of which about 38 grammes are solids. The higher weights correspond with the ingestion of vegetable foods rich in cellulose, the lower, with mixed diets and diets high in their proportion of meat.

The *Odor* is due to indole and skatole (see page 114) and to hydrogen sulphide, etc. It varies with the character of the diet, being greater with meat diets, and less with those composed largely of vegetables.

The *Color* is normally some shade of brown, from the presence of the pigment hydrobilirubin (stercobilin). It varies with the diet, being darkest with a meat diet, and is affected by many drugs, as well as by pathological conditions. Cathartics may produce greenish stools, possibly by hurrying through the intestine unchanged biliverdin from the bile, or the stools may be distinctly greenish-yellow from the presence of an excess of bile. They may be clay-colored from lack of bile (acholia) or from excess of fat. They may be black after ingestion of iron salts, or salts of bismuth, from the formation of the sulphides of these metals, or they may be directly pigmented by such drugs as methylene blue. Tarry or black stools may be caused by the presence of blood.

The *Reaction* is generally neutral, sometimes alkaline, to litmus. A meat diet tends to produce alkalinity, while with excess of carbohydrates the reaction may become acid. Infant stools are usually acid. To test, spread the fecal matter on one side of the test-paper and look for the resulting color on the reverse side.

The *Specific Gravity* is not easily determined. It varies generally

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between 1.045–1.070, but with fatty stools may be as low as 0.935. The floating of the normal stool is due to the gas contained.

Fats. The term fat in fecal analysis includes generally all substances soluble in ether—the fatty acids, soaps, lecithin, cholesterol, cholalic acid, etc.

Acidify slightly, mix with sand, evaporate to dryness, and extract with ether in the Soxhlet apparatus.

Normally the "fat" present is largely of intestinal origin, and this may amount to about 25 per cent. by weight of the dry feces. In pathological conditions, absence of bile, etc., the fat may reach 50 per cent. Excess of saponified fat indicates defective absorption. Excess of unsaponified fat indicates absence of bile or imperfect pancreatic digestion.

The *Carbohydrates* are identified and estimated with much difficulty, and may be omitted from ordinary clinical examinations.

Nitrogen, normally about 1 per cent. of the moist feces, is estimated by the Kjeldahl process. See page 126.

Examination of Feces.

Practically, the examination of the feces is more macroscopic and microscopic than chemical, the latter tests being confined clinically to a determination of the reaction (see above) and to the tests for blood. The reaction, owing to the changes which take place, should be determined as soon as possible after the passing of the stools.

For the *microscopic examination* the stools if watery may be placed in a shallow dish and there examined. If the stools be firm or pasty they should be broken up and stirred with water. Macroscopically they are inspected for the presence of pathological products, gall stones, enteroliths, intestinal parasites and undigested food.

Microscopically the stools are examined for food residues, muscle fibers, starch granules, etc.; for epithelium, blood corpuscles, leucocytes, mucus, pus, and bacteria; and for the various possible crystalline elements, such as cholesterol, hematoidin, triple phosphates, Charcot-Leyden crystals, and the salts of lime.

The presence of *Blood*, even in minute amount—the so-called "occult blood," is often of great diagnostic importance, notably so in cases of gastro-intestinal cancer, and in gastric and duodenal ulcer. Of the two tests given below the Aloin-Turpentine test is that generally preferred.

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Weber's Guaiac Test for Blood. Mix a small portion of the feces with sufficient 30 per cent. acetic acid to form a fluid mass. Shake with several portions of ether. Pour off the ether, and after filtering, add a fresh alcoholic solution of guaiac (1–60), drop by drop until the fluid becomes turbid, then add a few drops of hydrogen peroxide. A blue coloration indicates the presence of blood.

Aloin-Turpentine Test for Blood. Reduce 5 grammes of the stool to a semi-fluid mass with distilled water. Extract with an equal volume of ether to remove fat, and discard this etherial extract. Add one-third volume of glacial acetic acid and extract again with several 10 c.c. portions of ether; finally filtering the etherial solution.

To 2 c.c. of this acid-ether solution add 2 c.c. of a dilute solution of aloin in 70 per cent. alcohol and 2 c.c. of ozonized turpentine. Shake gently. If blood be present the mixture turns pink and finally becomes cherry-red. If the test is to be considered positive this color-change must occur within fifteen minutes.

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THE BLOOD.

THE blood is an opaque, viscid, reddish fluid, with characteristic odor and a salty taste. The *Specific Gravity* averages about 1.060, but may vary from 1.045 to 1.075. The *Color*, due to the contained hemoglobin, varies, with the degree of oxidation of this substance, from scarlet in arterial blood to bluish-red in venous blood. The depth of color naturally depends upon the amount of hemoglobin present and therefore varies in certain diseased conditions, *e. g.*, being pale in chlorosis, anemia, leucemia, etc. Certain poisonous gases also affect the color, hydrogen sulphide producing a brownish-green tint, carbon monoxide a cherry-red, chlorine a greenish-yellow, and arsenetted hydrogen a brown tint. In poisoning by potassium chlorate, aniline, hydrocyanic acid, nitrobenzol, etc., the blood may have a brownish-red or chocolate color. The *Reaction* is alkaline to litmus, the alkalinity being due principally to the disodium phosphate, and sodium hydrogen carbonate, contained.

Anatomical Composition:

Blood
- Plasma, Averages 60 p. c.
  - Serum
  - Fibrinogen, Average 0.25 p. c.
- Corpuscles, Average 40 p. c.
  - Red Corpuscles
  - Leucocytes
  - Blood Platelets

Clot, including some interstitial serum.

Chemical Composition:

	Blood.[1] Man.	Blood.[1] Woman.	Serum.[2]	Red Corpuscles[3] (Moist).
Water,	77.90	79.10	90.79	68.80
Solids,	22.10	20.90	9.21	31.20
Albumin, Serum-globulin,	7.60	7.60	4.52 / 3.10	2.63
Hemoglobin,	13.44	12.18	——	27.52
Fibrinogen,	0.22	0.22	——	——
Extractives and Fat,	0.16	0.16	0.71	0.24
Mineral Salts,	0.68	0.74	0.88	0.81

[1] Becquerel and Rodier. [2] Hammarsten.
[3] Calculated from analyses by G. Schmidt and Hoppe-Seyler.

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The gases in human blood, measured at 0° C. and 760 mm. are in per cent. by volume, as follows: Arterial blood: Oxygen, 21; Carbon dioxide, 38; Nitrogen, 1–2. Venous blood: Oxygen, 8–12; Carbon dioxide, 46; Nitrogen, 1–2.

The Mineral Salts of blood consist of chlorides, carbonates, phosphates and sulphates of sodium and potassium, with phosphates of calcium and magnesium. In the serum the salts of sodium are the more abundant, in the corpuscles, the salts of potassium. The iron from the hemoglobin averages about 0.05 per cent. of the blood.

THE PLASMA. The plasma is a viscid, yellowish liquid with strong alkaline reaction. Owing to a change in one of its constituents, Fibrinogen, it coagulates readily, separating into Fibrin and Serum, the change being effected by a special unorganized ferment, *thrombin*, a nucleo-proteid, a product of the disintegration of the leucocytes and blood platelets. The Fibrin so formed is an insoluble, grayish-white, stringy substance, elastic and retractile. The *coagulation is hastened* by raising the temperature to a little above that of the body, by contact with most foreign matter, by agitation, and by addition of a small amount of a neutral salt. The *coagulation is hindered* by a low temperature, by contact with a living vascular surface or with oils and oily surfaces, by addition of a considerable amount of a neutral salt, by infusion of leaches, by small amounts of alkalies, by addition of acetic acid, by excess of carbon dioxide and by excess of water. Coagulation takes place only in the presence of calcium salts and may, therefore, be prevented by allowing the blood to flow into a solution of potassium oxalate of such strength that the resulting mixture will contain about one-tenth per cent. of the reagent. The calcium salts are precipitated as calcium oxalate.

THE SERUM differs from the plasma only in the absence of fibrinogen, and hence may be obtained, after coagulation, as an exudation from the clot, any remaining corpuscles being removed by means of the centrifuge. The chief *Proteins* of the serum are Serum-Albumin and Serum-Globulin, the latter being known, also, as Paraglobulin and as Fibrinoplastin. The two may be easily separated by saturation with magnesium sulphate, the albumin remaining in solution while the globulin is precipitated.

The principal "*Extractives*" of the serum are the neutral fats, most abundant after a meal of fatty food, and Cholesterol, an

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alcoholoid substance, $C_{27}H_{45}OH$, widely distributed in the body. Lecithin, a complex phosphorus-holding body characteristic of nerve tissue, is present in the blood in small amount. Other extractives are Urea, Uric Acid, Creatine, Xanthine, Hypoxanthine, Hippuric Acid, and Carbohydrates. The *Mineral Salts* of the serum include sodium chloride, carbonate, sulphate and phosphate, smaller percentages of the corresponding potassium salts, and the phosphates of calcium and magnesium.

THE BLOOD CORPUSCLES (HEMOCYTES). The *Leucocytes*, also known as the "white" or "colorless" corpuscles, are typical cells with nucleus and protoplasm. They average from 5–10,000 per cubic mm. of blood, and vary in size from 0.005 to 0.010 mm. in diameter. The protoplasm of the cell consists chiefly of cell-globulin and cell-albumin, but contains, also, glycogen, fat, lecithin, cholesterol, and some mineral matter. The nucleus is characterized by the presence of a phosphorus-holding body, nuclein. Various forms of leucocytes are recognized: Large cells with polymorphic nuclei, called polynuclear; small mononuclear forms; and transitional forms. The leucocytes are also classified according to the staining of the contained granules: Acidophiles or eosinophiles, staining with acid stains, *e. g.* eosin; basophiles, which stain with basic stains, *e. g.* methylene blue; and neutrophiles, which stain with neutral stains, *e. g.* combined methyl blue and acid fuchsin. The following methylene-eosin stain is useful: 60 parts of a concentrated water solution of methylene blue, 20 parts of a one-half per cent. solution of eosin in 70 per cent. alcohol, 40 parts of distilled water, and 12 drops of 20 per cent. potassium hydroxide. With this stain the red corpuscles are colored a light red; the leucocytes a pale blue, with their nuclei dark blue; the eosinophilic granules, a deep red. The best results are obtained by staining for 24 hours, but fair results may be obtained by heating the staining fluid for 15 minutes.

Ehrlich's triple stain (Orange G., acid fuchsin, and methyl green) colors the red corpuscles to a copper tint; the neutrophilic granules, violet; the eosinophiles, greenish-blue; the nuclei of lymphocytes, deep blue; the nuclei of the large mononuclear cells, a pale blue; the nuclei, when present, of red corpuscles, an intensely dark blue.

The *Blood Platelets*, or Plaques, measure from 0.002 to 0.004 mm. in diameter. Nothing definite is known as to their composition. They average about 600,000 per cubic mm.

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The *Red Corpuscles* (Erythrocytes) measure from 0.007 to 0.008 mm. in diameter, in man, and number about 5,000,000 per cubic mm.

Nearly 90 per cent. of the dried red corpuscles consist of *Hemoglobin*, an iron-holding conjugate protein, $C_{600}H_{960}N_{154}FeS_3O_{179}$ (Preyer), crystalline but not diffusible. In arterial blood the hemoglobin is loosely combined with an additional molecule of oxygen forming *Oxyhemoglobin*, a substance soluble in water and in alkaline liquids, insoluble in absolute alcohol, ether, chloroform or acids. The additional oxygen molecule may be easily separated by means of reducing agents. *Methemoglobin*, a similar substance formed during the drying of blood, and also by the addition of potassium ferricyanide or of amyl nitrite, differs from the last in that the additional oxygen is more closely combined. With carbon monoxide, as in poisoning from inhalation of the gas, hemoglobin forms a cherry-red combination, known simply as *Carbonic-oxide-hemoglobin*. CO-hemoglobin, unlike oxyhemoglobin, is not reduced by treatment with ammonium sulphide. Hemoglobin consists of a brownish pigment, *Hematin*, $C_{34}H_{34}N_4FeO_5$ (Gautier), united with a basic protein, globin. The pigment may be demonstrated by adding sodium hydroxide to the blood. By heating blood in presence of glacial acetic acid and a little salt, the *Hydrochloride of Hematin*, formerly known as *Hemin* may be separated in dark, brownish, triclinic plates and prisms. *Hematoporphyrin*, $C_{34}H_{34}N_4O_5$ (Gautier), is artificially produced by the action of sulphuric acid on hematin. It is produced naturally within the body, and is sometimes present in the urine. *Hematoidin*, $C_{16}H_{18}N_2O_3$, formed in old extravasations, appears to be identical with the bile pigment bilirubin.

Absorption Spectra of Blood Pigments.—In blood diluted with 250 parts of water *Oxyhemoglobin* gives two absorption bands between D and E, that nearer D being the narrower and darker. *Hemoglobin* gives one broad band extending from near E to a little beyond D. *Carbonic-oxide-hemoglobin* gives a spectrum similar to that of oxyhemoglobin, but the bands are narrower and slightly nearer the violet end. Addition of a few drops of very dilute tartaric acid has no effect upon the CO-hemoglobin spectrum while it reduces the two bands of Oxyhemoglobin to the single band of hemoglobin. *Methemoglobin* gives three bands, one in the red between C and D, the others in the position of the oxyhemoglobin

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bands. *Alkaline Hematin*, made by dissolving hematin in strong alkali, or by adding strong alkali to a solution of oxyhemoglobin or to diluted defibrinated blood, gives one ill-defined band extending from D toward C. *Hemochromogen*, a substance formed by addition of ammonium sulphide to a solution of alkaline hematin, gives one band midway between D and E, and a second, fainter, band between E and b. This spectrum is one of the most useful for purposes of blood identification. The band between D and E is given in very dilute solutions. Acid solution of *Hematoporphyrin* gives a dark band midway between D and E and a fainter, narrower band to the left of D.

The Blood in Disease.

In *Leucocytosis*, physiological and pathological, the leucocytes are increased. In *Anemia* the red corpuscles are decreased, and there is a proportionate decrease in hemoglobin; the leucocytes may be increased. In *Pernicious Anemia* the red corpuscles are greatly decreased and are irregular in size and shape (irregularity in shape = poikilocytosis; large cells = megalocytes; small cells = microcytes); the hemoglobin is decreased, but not in proportion. Leucocytes are not materially increased and may be normal. In *Leucocythemia* the leucocytes are greatly increased and the red corpuscles are slightly decreased. In the spleno-medullary form of the disease the increase is chiefly of the large mononuclear and polynuclear leucocytes. In the lymphatic form the increase is chiefly of the small mononuclear leucocytes. In *Chlorosis* the red corpuscles may be normal or slightly decreased; the hemoglobin is greatly decreased.

In hemoglobinemia the hemoglobin passes from the corpuscles to the plasma, and may be present in the urine (hemoglobinuria). In septicemia, the hemoglobin is reduced in amount, while there is an increase in the number of leucocytes and an increase, also, in the amount of fat, urea, etc. In liver and biliary disorders, bile pigment, and in obstruction of the bile ducts, bile acids may appear in the blood. In acute yellow atrophy of the liver, there is a considerable amount of leucin and tyrosin in both blood and urine. In kidney diseases there may be a decrease in the percentage of albumin, while urea, fats and fibrin are all increased. In diabetes mellitus there is an increased amount of dextrose, and ethyldiacetic acid may be present.

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Examination of Blood.

Specific Gravity.—Prepare a mixture of chloroform and benzol of a specific gravity of about 1.060 (about 1 part chloroform and 2 parts benzol), and add a drop of the blood. If the drop rises to the surface, add more benzol; if it sinks, add more chloroform. When the drop neither rises nor sinks, determine the specific gravity of the mixture.

Reaction.—Test with glazed litmus paper, or with ordinary litmus paper by first saturating the latter with concentrated sodium chloride solution and then, after dipping into the blood, washing it free from corpuscles by means of the same saline.

The alkalinity may be determined quantitatively (Löwy's Method) by allowing 5 c.c. of the blood to flow into a small flask, with long neck, containing 45 c.c. of 0.25 p. c. ammonium oxalate. Titrate with $\frac{N}{25}$ tartaric acid, using as an indicator lacmoid paper which has been previously washed in a concentrated solution of magnesium sulphate. The number of cubic centimetres required to neutralize the 5 c.c. of blood multiplied by 0.0016, and this by 20, gives the degree of alkalinity, for 100 c.c. of blood, in grammes of sodium hydroxide—the normal is from 0.300 to 0.325 gramme.

Enumeration of Corpuscles by the Thoma-Zeiss hemocytometer. The apparatus consists of a capillary pipette graduated at 0.5, 1.0, and 101 cu. mm., and of a cell, or counting plate, divided into small squares, the space over each square, with the cover glass in position, having a capacity of one-four thousandth cu. mm. For dilution of the blood prepare a 3 p. c. salt solution, or a 2.5 p. c. solution of potassium dichromate, or, better, use Toison's fluid, which is as follows: Distilled water 160 c.c., neutral glycerol 30 c.c., sodium sulphate 8 grammes, sodium chloride 1 gramme, and methyl violet, 0.025 gramme.

Prick the skin of the ear lobe or of the finger and draw the blood into the pipette to the 0.5 or 1.0 mark. Cleanse the end of the pipette and draw up the diluting fluid to the 101. mark. After thorough mixing of the blood and diluting fluid drive out the excess of the latter from the capillary stem and place the diluted blood on the counting stage. Cover carefully, and, after letting it stand a few moments, count the corpuscles in a number of squares and calculate the average number per square. To obtain the number of corpuscles per cu. mm., if 0.5 cu. mm. of blood were

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taken, the average number of corpuscles per square is to be multiplied by 800,000 (= 4000 × 200), while if 1.0 cu. mm. of blood was taken the average number of corpuscles per square is to be multiplied by 400,000 (= 4000 × 100).

The proportion of white to red corpuscles may be approximately determined during the counting, the saline solution rendering prominent the nuclei of the former, or, if Toison's fluid has been used, the leucocytes are conspicuous because of their staining. When an accurate counting of the leucocytes is desired it is well to prepare a special dilution of the blood, 1–10 or 1–20, using for the purpose either the Toison's fluid, or a one-third per cent. acetic acid, the latter rendering the leucocytes prominent by destruction of the red corpuscles. To differentiate the several kinds of white corpuscles, neutrophiles, eosinophiles, etc., it is necessary to prepare a stained specimen of the blood. For the methods of staining, and for description of these cells, see page 203 and text-books of histology.

The centrifuge with hematocrit attachment affords an easy and rapid approximate method for the enumeration of corpuscles. Ample instructions accompany the instrument.

Estimation of Hemoglobin, by the hemoglobinometer of Gowers. Two glass tubes are provided, one graduated into 120 parts for the blood, the other containing a preparation of glycerine jelly so tinted with carmine and picrocarmine that its color is that of normal blood diluted with 100 parts water. Twenty cubic mm. of blood are measured by means of a capillary pipette into a few drops of distilled water previously placed in the graduated tube. The blood is then diluted until the tint is the same as that of the standard. If the blood be diluted to the 100 mark then the hemoglobin is normal; if to the 50 mark, then one-half normal, etc.

Von Fleischl's hemometer is also largely used. In this instrument the diluted blood fills one-half of a small cylinder, the other having been filled with distilled water. Beneath the water compartment is a sliding strip of glass colored to represent varying percentages of hemoglobin. Viewed from above this glass strip is so adjusted that the light reflected through the two compartments shows exactly the same shade of color in each. The percentage of hemoglobin may then be read from the scale on the instrument.

It is important to compare the amount of hemoglobin with the number of red corpuscles. The percentage of hemoglobin divided

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by the percentage of red corpuscles gives the *Color Ratio* or *Index*. Thus, in a case of chlorosis, the hemoglobin was 30 p. c. of the normal, the red corpuscles were 90 p. c. of the normal and the Color Ratio, $\frac{30}{90}$ or 0.33 +.

Estimation of Hemoglobin from the contained iron. Evaporate a weighed quantity of blood to dryness, ignite at a dull red heat, treat the residue with hydrochloric acid and determine the iron quantitatively. If x equal the percentage of iron, then the percentage of hemoglobin in the sample equals x multiplied by 100, divided by 0.42.

Examination for Malaria Parasites. Dry a thin film of blood, fix, and stain for 5–6 minutes with methylene-eosin, page 203, wash in water, dry and mount in Canada balsam. The parasites are stained a dark blue.

The parasites may be looked for, also, directly, in a thin spread beneath a cover glass, using an oil-immersion lens, or, as follows: Prepare a 0.6 per cent. salt solution, color with methylene blue, filter, and sterilize. Cleanse the finger, apply a drop of stain, and prick the finger through the stain. Touch cover glass to the drop and mount a thin layer, sealing the edges with paraffin wax.

Widal Reaction for Typhoid (Macroscopic). Five c.c. Koch's nutrient bouillon are sown with a fresh culture of the typhoid bacillus. Mix with 5 drops of serum. If the mixture becomes turbid, then flocculent, and, after 24 hours, shows a flaky precipitate, the reaction is regarded as positive.

Tests for Blood.

The suspected solution may be examined microscopically for blood corpuscles, and spectroscopically for blood pigment. If the blood be fresh the spectrum of oxyhemoglobin may be obtained; older blood will probably show methemoglobin. In the case of stains on cloth, extract with a little water, add a few drops of sodium hyposulphite, a few drops of strong sodium hydroxide, and then examine for the spectrum of hemochromogen.

The Guaiacum Test. Mix the suspected fluid with 3–4 drops of a freshly prepared tincture of guaiacum resin. Float an etherial solution of hydrogen dioxide on the surface of the mixture, and let it stand without shaking. In presence of hemoglobin a blue color will be developed.

The guaiacum test is given, more or less perfectly, by substances

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other than blood, *e. g.*, by milk, pus, saliva, various mineral compounds, oxidizing agents, etc., but in most cases the blue color is obtained on addition of the guaiacum alone, while with blood no color is obtained until after the addition of the dioxide. Old oil of turpentine that has been well exposed to light and air may be used instead of the etherial hydrogen dioxide solution.

The "Hemin" Test. To a drop of fresh blood on a glass slide add a drop or so of glacial acetic acid and heat slowly to boiling. Cool and examine under the high power of the microscope for crystals of hematin hydrochloride, "hemin," minute dark brown triclinic plates and prisms, often in star-shaped clusters.

In the examination of a stain on cloth, etc., scrape the stain and place the scrapings (or place a few fibres of the stained material) on a large glass slide. Add 2–3 small crystals of sodium chloride, and a few drops of glacial acetic acid; warm gently for some time, then add, to the evaporated solution, two drops more of the acid, and heat to boiling. Cover with a cover glass and examine for the crystals. The treatment with acetic acid may advantageously be repeated several times.

As a sequel to the hemin test, dissolve the crystals obtained in a few drops of sodium hydroxide. If sufficient hemin be present, the solution is dichroic, green and red. Evaporate to dryness in a small porcelain crucible and test the residue for iron.

A stain may be further tested as follows: Soak the stain in water and place drops of the aqueous solution on a number of watch glasses. To one add nitric acid, to another add acetic acid and potassium ferrocyanide; if the stain be recent, precipitates should be obtained in both tests. To a third portion add a drop of ammonium hydroxide; the red color remains, while with vegetable reds it would probably be destroyed. Heat to boiling—a gray turbidity is produced—add a few drops of sodium hydroxide—the turbidity disappears and the solution exhibits a green-red dichroism.

Adler's Benzidin Test. Add an equal volume of 3 per cent. hydrogen dioxide to 5 c.c. of a *fresh* saturated solution of benzidin, then 1 c.c. of the acidified (acetic acid) aqueous solution to be tested. A green or blue color will indicate the presence of even a very minute amount of blood.

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MILK.

AVERAGE COMPOSITION OF MILK.

	Human Colostrum (Tidy).	Human Milk (Lehman).	Cow's Milk (König).	Goat's Milk (König).
Water,	84.077 p. c.	88.3 p. c.	87.17 p. c.	85.6 p. c.
Solids,	15.923 "	11.7 "	12.83 "	14.4 "
Casein,	3.228 "	1.2 "	3.02 "	3.2 "
Albumin,		0.5 "	0.53 "	1.1 "
Fat,	5.781 "	3.8 "	3.69 "	4.8 "
Lactose,	6.513 "	6.0 "	4.88 "	4.5 "
Salts,	0.335 "	0.2 "	0.71 "	0.8 "

The salts consist of calcium phosphate along with the chlorides and phosphates, of calcium, magnesium, sodium, and potassium, with a small amount of iron and a trace of silica. There are, also, certain gases in solution: According to Pflüger, 100 volumes of milk contain 7.60 of carbonic anhydride, 0.10 of oxygen and 0.70 of nitrogen.

Frankland gives for woman's milk an average of 11.4 per cent. solids, divided as follows: Proteins, 2.7; Fat, 3.5; Lactose, 5.0; Salts, 0.2. For cow's milk he gives an average of 12.5 per cent. solids divided into: Proteins, 4.2; Fat, 3.8; Lactose, 3.8; Salts, 0.7. Rotch gives as a normal woman's milk, 12.5 per cent. of organic solids, including, Fat, 4.0; Lactose, 7.0, and Casein, 1.5. The variations in the stated composition of woman's milk are due partially to individual peculiarities and partially to the methods of sample collection. "Fore milk" gives about 10 per cent. solids, while "stripping" may give as high as 15 per cent. There is also a variation during the day, afternoon milk being high in solids, and the composition is further affected by age, temperament, number of pregnancies, diet, exercise, regularity of nursing, etc.

A milk may be described as "over-rich," "abundant normal,"

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"scanty normal," "abundant poor," "scanty poor." A multipara of forty or over generally yields a poor milk. Irregularity in nursing, with too long intervals, produces a poor milk, while too frequent nursing produces a concentrated milk, an "over-rich scanty" milk.

Pathological alterations may occur after the administration of certain drugs, atropine, colchicum, chloral, opium, etc., and in morbid conditions. In osteomalacia the salts are increased; in acute fevers the amount decreases, the casein increases; in syphilis the salts increase, while both casein and fat decrease. Neurotic influences, catamenia, and starvation lower the percentage of fat and to a less degree the sugar, while the casein may be slightly increased. An over-rich milk may be due to too liberal feeding without proper exercise, the solids in such cases reaching 15–17 per cent.

Micro-organisms are invariably present in all natural milk which has been, even momentarily, exposed to the air. Miquel found in fresh milk 9000 bacteria per cubic centimetre; in the same sample, one hour later, 31,750; nine hours later, 120,000; and after twenty-four hours, 5,600,000. The germs of infectious diseases may be recognized by physiological and microscopical tests. Cow's milk occasionally exhibits an abnormal appearance due to the presence of chromogenic bacilli, not necessarily, however, pathogenic in character. "Red" and "blue" milks are examples of this phenomenon.

Milk Products. By the addition of rennet, the casein of the milk is separated as a coagulum and carries with it most of the fat, the resulting mass constituting a *cheese*. The liquid remaining after separation of the cheese is termed *sweet whey*, and has practically no food value.

The *souring of milk* results in the formation of a precipitate of caseinogen, the *curd*, and of a liquid, the *acid whey*, the lactose of the milk having been changed by the bacterium lactis into lactic acid. As a result of further decomposition, butyric acid is produced, and may be recognized by its odor.

Koumiss is prepared by treating milk with a special ferment, the lactose thereby undergoing alcoholic fermentation. Koumiss differs from whey in that it contains nearly all of the nutrient constituents of the original milk, and it differs from milk in that it is an effervescing alcoholic fluid. True koumiss is prepared from

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mare's milk. *Kefyr*, a similar preparation, is made by the action of a microbic ferment, the bacillus Caucasicus. *Galazyme* is prepared from cow's milk, by the fermentation of added cane sugar, by means of brewers' yeast.

Buttermilk, remaining after the separation of the butter in butter making, contains the casein of the milk, the sugar, the salts, and a portion of the fat, and is, therefore, a nutritious food.

Clinical Analysis of Milk.

Quantity. The normal amount secreted by a healthy woman may be placed at from 900 to 1000 c.c. daily. A cow in good condition secretes 6000 to 7000 c.c. daily, or about four times its body weight in the year.

Reaction. Tested with litmus paper, human milk is normally faintly alkaline. The milk of the cow and other herbivora may be alkaline or amphoteric in reaction when first passed, but becomes acid on standing, the acidity of 100 c.c. milk being normally neutralized by 14–16 c.c. of decinormal alkali. Milk of the carnivora is acid in reaction.

Specific Gravity. The specific gravity of cow's milk varies normally from 1.028 to 1.034; human milk may vary from 1.024 to 1.034 with an average of 1.030–31. The specific gravity increases for several hours after the milk has been drawn, the increase reaching as high as 0.002. It is raised by the removal of the cream and lowered by the addition of water. When the milk has suffered both of these operations, therefore, the specific gravity may be normal. *Method.*—The specific gravity is usually taken with a hydrometer after a thorough shaking of the sample. When the temperature of the milk departs considerably from the temperature of registration of the hydrometer (usually 60° F.) a correction must be made. Sufficiently accurate results may be obtained by subtracting 0.001 from the hydrometer reading for each 10° below 60° F., or by adding 0.001 to the reading for each 10° above 60° F.

A hydrometer with specially constructed scale, known as the *lactometer*, is frequently used in the municipal control of milk. Upon this instrument the 0° mark corresponds to a specific gravity of 1.000, that of pure water, while 100° corresponds to a specific gravity of 1.029, the minimum acceptable specific gravity for pure milk. The scale is commonly extended to 130°, 120° corresponding to a specific gravity of 1.034, the maximum for pure milk.

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FAT. (Cream.)—(*a*) *By the Creamometer.*—A glass cylinder graduated into 100 parts from above downward, is filled to the zero mark with the well shaken sample. After standing for 24 hours in a cool place, the percentage of separated cream may be read directly from the graduations. This should be between 10 and 20 volumes. Comparing with the specific gravity, less than 10 volumes in a milk of specific gravity above 1033 indicates skimming. Less than 20 volumes in a milk of specific gravity below 1029, indicates the addition of water. There are, however, several possible sources of error in this method. Cream varies in consistency and consequently in bulk, and, moreover, the addition of water causes a rapid separation of the cream with an *apparent* increase in quantity.

(*b*) *By Feser's Lactoscope.*—This method is based upon the fact that the relative opacity of milk depends chiefly upon the number of suspended fat globules. Four c.c. of milk are introduced into the instrument and water added until the black lines upon the inner cylinder are plainly visible. The volume of the mixture indicates, by graduations on the outer tube, the percentage of fat by weight, in the sample. Whole milk should show three per cent. or over, by this method.

(*c*) *Werner-Schmid Method.*—Ten c.c. of milk are measured into a test-tube of 50 c.c. capacity and 10 c.c. strong hydrochloric acid added. The tube is stoppered and heated in a water-bath until the mixture turns a rather dark brown, when it is cooled and shaken with 30 c.c. of anhydrous ether. A wash-bottle-like arrangement of cork (not rubber) and tubes is now substituted for the stopper, and the lower end of the exit tube, which is recurved, is so placed as to rest just above the line dividing acid and ether. The ether is blown out into a weighed flask* and two more extractions are made, using, for each, 10 c.c. of anhydrous ether, and adding the extracts to that first obtained. Distil off the ether, dry the fat at 110° C., and weigh.

(*d*) *Babcock Method.*—This method depends upon the destruction of the proteins with concentrated sulphuric acid and the separation of the melted fat by means of a centrifuge.

To 17.6 c.c. of milk in a specially designed bottle with long, narrow, graduated neck, add an equal volume of sulphuric acid,

* A separating funnel may be used for this separation instead of the arrangement described.

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sp. gr. 1.83. After gentle shaking the mixture is centrifuged for five minutes. Boiling water is now added to force the melted fat into the neck of the bottle where the amount can be accurately read from the graduations. Smaller tubes requiring only 5 c.c. of milk for the test are made for clinical purposes.

PROTEINS. *Total.*—The milk is diluted with an equal volume of water, a little common salt solution is added, and, then, an excess of tannic acid. The precipitate is washed with dilute alcohol and then with cold water, and the nitrogen contained is determined by Kjeldahl's method, for which see page 126.

Casein.—Dilute the milk with an equal volume of a saturated solution of magnesium sulphate, and then add powdered magnesium sulphate to complete saturation. Filter, wash the precipitate with saturated solution of magnesium sulphate, and determine the nitrogen by Kjeldahl's method.

Lact-albumin.—The albumin may be obtained by subtracting the amount of casein, found above, from the total proteins, or, it may be determined as follows: To 5 grammes of milk add 50 c.c. saturated magnesium sulphate solution, warm to 40–45° C., and wash the precipitated casein (and globulin) with a warm solution of magnesium sulphate. Neutralize the filtrate with sodium hydroxide, add 0.3 c.c. of 10 per cent. acetic acid, and boil to precipitate the albumin.

In the above analyses, the nitrogen found, multiplied by 6.37 in the case of cow's milk, or by 6.34 in the analysis of human milk, gives the amounts of total protein, of casein, and of albumin.

The determination of the proteins in milk offers many difficulties, and is generally omitted in the ordinary clinical examination, as is, also, the test for sugar which follows.

LACTOSE. Ten c.c. of the milk are diluted exactly with 30 c.c. of water, a few drops of acetic acid added, and the precipitated caseinogen filtered off. The filtrate is raised to the boiling point to coagulate the albumin, which is then removed. The protein-free filtrate is now either boiled with dilute hydrochloric acid to convert the lactose into glucose, and the latter determined by means of Fehling's solution (see page 118), or, the lactose may be directly titrated, 10 c.c. of Fehling's being decomposed by 0.0676 gramme of that carbohydrate. Neither method is accurate, but those which are more exact are too elaborate for clinical application.

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TOTAL SOLIDS. (*a*) *By Calculation.*—An approximation, sufficiently accurate for clinical purposes, particularly in the examination of mother's milk, may be made by means of Hehner and Richmond's modified formula, $T = 0.25\ G + 1.2\ F + 0.14$. T = Total Solids. F = Fat percentage, as determined by Feser's lactoscope, or by extraction with ether. G = second and third decimals of the specific gravity; *e. g.*, if the specific gravity is 1.030, then G = 30.

The same formula, transposed, may be used to calculate the fat, the total solids and specific gravity being known.

(*b*) *By Weight.*—Two grammes of milk are accurately weighed in a covered platinum dish with about 10 grammes of dry sand or powdered gypsum. The milk is then evaporated and the whole carefully dried at 100° C., until a constant weight is obtained. The loss in weight gives the water of the milk, and, by difference, the total solids.

ASH. By incinerating the solids obtained in the last test, the percentage of ash may be determined, or, better, make a separate determination as follows: To 20 grammes of milk in a weighed dish add 6 c.c. of nitric acid, evaporate to dryness and burn at a low red heat until the ash is free from carbon.

DETECTION OF ADULTERATION IN MILK.

Certain substances, *e. g.*, *sodium carbonate*, *salicylic acid*, *borax*, *boric acid*, etc., are occasionally added to milk for the purpose of preservation. The presence of such substances will probably be indicated by an increase in the amount of ash, and special tests may then be applied. For *salicylic acid* and *salicylates*, acidify with hydrochloric acid, filter, and shake the whey with ether. Evaporate the ether and test the residue (see page 66). To test for *borax* place one drop of milk in a porcelain dish with 2 drops of strong hydrochloric acid and 2 drops of a saturated turmeric tincture. Dry on a water-bath and when cool, by means of a glass rod, add one drop of ammonium hydroxide—a slate-blue color, changing to green, is developed if borax be present. To separate *borax* or *boric acid* from the milk for testing, 100 c.c. are heated to boiling in a covered beaker and 8 c.c. of nitric acid (1–50) are added. The milk is then cooled, filtered, one-eighth gramme of sodium carbonate added, evaporated to dryness and burned to a gray ash. The soluble portion of this ash is now tested (see page 61).

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Formaldehyde (Formalin), may be tested for as follows (Hehner's Test): Dilute the milk with an equal volume of water and float it over 90–94 per cent. sulphuric acid, the latter containing a trace of a ferric salt. If formaldehyde be present a violet ring is formed at the junction of the two liquids; in absence of formaldehyde the ring has a greenish tinge.

Leach's Test: Ten c.c. of milk are mixed with 10 c.c. of commercial hydrochloric acid in a porcelain dish and gently heated to boiling, shaking frequently to break up the curd. A violet color shows the presence of formaldehyde. Better results may sometimes be obtained by making the test as follows: Heat 1 c.c. of milk with 4 c.c. of strong commercial hydrochloric acid. If a yellow liquid is formed dilute the milk with 2 or 3 volumes of water and repeat. A violet color is obtained if the formaldehyde is not over 0.1 per cent. The hydrochloric acid used in this test must contain a trace of ferric chloride, hence the use of the commercial acid as indicated above. If C. P. acid be used add 1 c.c. of a 10 per cent. solution of ferric chloride for each 500 c.c. of the acid.

Phenylhydrazin and Sodium Nitroprusside Test: Add a pinch of phenylhydrazin hydrochloride and a drop of a dilute solution of sodium nitroprusside, following this with an excess of sodium hydroxide. If formaldehyde be present a deep blue color is obtained, otherwise the color is grayish-green.

Phloroglucinol Test: Add to 10 c.c. of the sample 2 c.c. of a 0.1 per cent. phloroglucinol solution, and a few drops of sodium hydroxide. A reddish color is obtained when the milk contains four parts of formaldehyde per million. The reaction is most pronounced with milk containing about 0.5 per cent., and fails with milk containing more than 3.0 per cent.

For other tests for formaldehyde, see page 99.

Of adulterants proper, *water* is by far the most common and will be detected by variation in the specific gravity, total solids, etc. *Annatto*, added to increase the rich appearance of the milk, is not of itself harmful. Its presence may be detected by rendering the milk alkaline with sodium bicarbonate and soaking in it, for several hours, strips of filter paper. These latter will gradually acquire a yellow tint. Or, annatto may be tested for simply by allowing the milk to stand in a tall glass, when the lower stratum, instead of becoming blue-white, will remain of a yellowish tint. *Aniline*

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orange may be recognized by the pink color of the curd obtained on the addition of dilute hydrochloric acid. *Starch* may be tested for by the addition of iodine solution, a blue color being developed. *Cane sugar* will reveal itself in the taste and in the proportion of total solids, as well as in the percentage of sugar found. Boil 10 c.c. of the milk with 0.1 gramme of resorcinol and 1.0 c.c. of hydrochloric acid for five minutes. In presence of cane sugar a red color is obtained. Or, cane sugar may also be detected by the blue coloration obtained on heating a 10 c.c. sample with 2 c.c. of a saturated solution of ammonium molybdate and 8 c.c. hydrochloric acid (1–8), on the water-bath, for 5 minutes, at 80° C. *Chalk* will be deposited on standing, and may be tested for in the ash. *Gelatin* is tested for as follows: To 10 c.c. of milk add 20 c.c. of water and 10 c.c. of an acid mercuric nitrate solution. (Dissolve metallic mercury in twice its weight of nitric acid of sp. gr. 1.42, and add 5 volumes of water.) Mix and shake vigorously, let stand 5 minutes, and then filter. If much gelatin is present the filtrate will be clouded. Add to the filtrate an equal bulk of a saturated solution of picric acid; a precipitate indicates gelatin.

Other substances, but rarely met with, are glycerol, magnesium carbonate, tragacanth, dextrin, and arrow-root. These will increase the total solids, and may be identified by special tests.

FORMULÆ FOR THE PREPARATION OF MODIFIED MILK (GRIFFITH).

Average percentage of fat in cream obtained by skimming = 16.

Average percentage of fat in centrifugal cream = 20.

Q = Total quantity of mixture desired.

F = Percentage of fat desired.

P = Percentage of protein desired.

L = Percentage of lactose desired.

C = Total cream required.

M = Total milk required.

W = Total water required.

S = Total sugar required.

$$C\ (20\ \text{per cent.}) = \frac{Q \times (F-P)}{16^*} \qquad M = \frac{Q \times P}{4} - C$$

$$W = Q - (C + M) \qquad S = \frac{Q \times (L-P)}{100}$$

* Note: The denominator of this formula is always 4 less than the percentage of fat in the cream used.

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Example: To prepare 8 bottles of 5 ounces each of a milk containing fat, 3 per cent.; proteins, 1 per cent.; and lactose, 6 per cent.; using centrifugal cream:

$$\text{Cream} = \frac{40 \times (3-1)}{16} = 5 \text{ oz.} \quad \text{Milk} = \frac{40 \times 1}{4} - 5 = 5 \text{ oz.}$$

$$\text{Water} = 40 - (5 + 5) = 30 \text{ oz.} \quad \text{Sugar} = \frac{40 \times (6-1)}{100} = 2 \text{ oz.}$$

The mixture should be rendered alkaline by the addition of about 5 per cent. of the total of lime water. In this example 5 per cent. of $40 = 2$. Therefore substitute 2 oz. of lime water for 2 oz. of water in the above, making the water 28 oz.

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WATER ANALYSIS.

A WATER may be examined *microscopically* for the determination of the living forms contained, for the low orders of vegetable life, the fungi, for disease germs, etc., or it may be examined *chemically* for dissolved mineral salts and for evidence of pollution by sewage or by excreta. The microscopical examination, unfortunately, has proved of uncertain value owing to the difficulty of positively differentiating the harmless from the disease-producing life-forms, and to the obvious difficulty of properly representing within the boundary of a microscopic field the general contents of any considerable body of water. Microscopically we seek evidence of cholera, of typhoid, etc.; chemically we seek evidence of the pollution by which such germs, or others, might obtain entrance to the source of supply. If the water be contaminated it is a menace to health, whether or not the germs of a particular disease happen to be present at the moment, and in the actual quart, or gallon, withdrawn for examination. The chemical analysis of water is, however, a matter for the expert, and it is rare that a simple clinical test will be of value.

COLLECTION OF SAMPLE.

Great care is necessary in collecting a sample of water for analysis. Preferably a two-gallon clean, sterile, glass container is used, and this, after introduction of the sample, is at once closed with a clean new cork previously boiled in water. After closing, the cork and neck of the bottle should be further protected with sterile cotton or paper and sealed with wax.

If the sample is drawn from a faucet the water should be run for five minutes before collection; if from a stream, it should be at a sufficient distance from the shore to avoid extraordinary contamination.

METHODS OF ANALYSIS.

BACTERIOLOGICAL EXAMINATION.—Cultures should be made at

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once in several kinds of nutrient media and a count made of the number of colonies which develop on agar from one cubic centimetre. The cultures may be microscopically examined later. Usually colon bacilli are found, but the successful isolation of typhoid bacilli, even in water known to be contaminated, is difficult.

COLOR.—The color of a water is determined, in common practice, by half filling a two-foot glass cylinder fitted with flat plate ends. The cylinder is held horizontally before an illuminated white surface, and the water column then viewed throughout its length.

ODOR.—The odor, if any, is noted before and after heating, the water being placed in a stoppered flask.

REACTION.—The reaction, which is normally faintly acid, is tested with lacmoid (blue with alkalies, red with mineral acids, but unaffected by carbonic acid) and with phenolphthalein (deep red with alkalies, colorless with acids, including carbonic acid).

TOTAL SOLIDS.—100 c.c. of the water are evaporated in a carefully weighed platinum dish. After drying, the weight of the dish plus residue is determined, and the weight of the residue then obtained by difference. By now igniting the residue at a low red heat, organic matter and some volatile mineral compounds are removed; cooling and weighing, we determine, by calculation, the *organic and volatile solids*, the *mineral and non-volatile solids*.

CHLORINE.—A standard solution of silver nitrate is prepared, of such strength (4.795 grammes per liter) that each c.c. is equivalent to 0.001 gramme of chlorine, or, the deci-normal silver nitrate solution described on page 88 may be used. To 100 c.c. of the water (if the chlorine be very small in amount evaporate 250 c.c. of water to 100 c.c.) add a few drops of potassium chromate solution, and then, from a burette, add the standard silver solution until a faint, but permanent, reddish tint is developed. The number of c.c. of silver nitrate added, multiplied by the equivalent of each c.c. will give the amount of chlorine in the sample.

PHOSPHATES.—500 c.c. of the water are slightly acidified with nitric acid and evaporated to 50 c.c. Add a few drops of dilute ferric chloride, and then ammonium hydroxide in slight excess, filter, and dissolve the precipitate in a little hot dilute nitric acid. Evaporate the solution to 5 c.c., add 2 c.c. of a solution of ammonium molybdate and warm. Phosphates are thrown down as

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a yellow precipitate, the amount of precipitate indicating the amount of phosphate present.

NITROGEN OF AMMONIUM AND OF ALBUMINOID COMPOUNDS.—*Solutions required. Sodium Carbonate:* 50 grammes of the pure salt, strongly heated, are dissolved in 250 c.c. of distilled water and boiled down to 200 c.c. *Standard Ammonium Chloride:*—0.381 gramme pure, dry, ammonium chloride, dissolved in 100 c.c. ammonia-free water. For use, 1 c.c. of this solution is diluted to 100 c.c., each c.c. of the diluted solution being then equivalent to 0.00001 gramme of nitrogen. *Ammonia-free Water:*—Acidulate distilled water with sulphuric acid and redistil from a glass retort. *Nessler's Reagent:*—Dissolve 10 grammes potassium iodide in 10 c.c. water and add, gradually, a saturated solution of mercuric chloride, with constant agitation, until a slight red precipitate remains undissolved. To this mixture add 30 grammes of potassium hydroxide, and when the solution is effected add 1 c.c. more of the saturated mercuric chloride. Dilute to 200 c.c., let settle, and decant off the clear liquid. *Alkaline Potassium Permanganate:*—200 grammes of potassium hydroxide and 8 grammes of potassium permanganate are dissolved in 1000 c.c. of distilled water, boiled down to 750 c.c., and again made up to 1000 c.c. with ammonia-free water.

Nitrogen of Ammonium Compounds, "Free Ammonia."—Place in a glass retort, properly connected with a condenser and receiver, 200 c.c. of distilled water and 10 c.c. of the sodium carbonate solution. Distil until on testing the distillate with Nessler's reagent no reaction is obtained. Introduce now, 500 c.c. of the water under examination, and continue the distillation at such a rate that 50 c.c. of distillate will be obtained in each 10 minutes. To each 50 c.c., collected separately, add 2 c.c. of Nessler's reagent, and compare the color obtained with a series of standards made up of measured amounts of the ammonium chloride solution diluted to 50 c.c. with ammonia-free water, and having 2 c.c. of Nessler's reagent added. The amount of nitrogen in the 50 c.c. of distillate will then be equal to the known amount of nitrogen in that ammonium chloride standard which gives the same depth of color with the Nessler's reagent as does the distillate. Continue the distillation and the "Nesslerizing" until no further color is obtained. The sum of the nitrogen in the distillates will give the "nitrogen of ammonium compounds" in the 500 c.c. sample under analysis.

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Total Nitrogen and Nitrogen of Albuminoid Compounds, "Albuminoid Ammonia."—Rinse out the retort and introduce 200 c.c. of distilled water and 50 c.c. of the alkaline potassium permanganate. Distil until the distillate gives no reaction with Nessler's reagent. Introduce 500 c.c. of the water under examination, distil, and "Nesslerize," as described in the last paragraph. The result will be "total nitrogen." Subtracting the "nitrogen of ammonium compounds," already determined, from the "total nitrogen" of this second operation, we obtain the "nitrogen of albuminoid compounds."

NITROGEN AS NITRATES.—*Solutions required. Phenol-sulphonic acid:*—37 c.c. of strong sulphuric acid added to 3 c.c. of water, with 6 grammes of pure phenol. *Standard Potassium Nitrate:*—0.721 gramme of pure, fused, potassium nitrate in 1000 c.c. of water. Each c.c. of this solution contains 0.0001 gramme of nitrogen.

Process.—Evaporate a measured volume of water to dryness in a platinum dish, add 1 c.c. of phenol-sulphonic acid, and, after thoroughly mixing with the residue, add 1 c.c. of water and 3 drops of strong sulphuric acid. Warm on the water-bath, add 25 c.c. of water, and an excess of ammonium hydroxide, then add water to 100 c.c. Compare the color of the solution (a yellow) with that obtained by similarly treating 1 c.c. of the standard potassium nitrate. The darker solution is diluted until the colors are equal. The amount of dilution being measured, and the amount of nitrogen in the 1 c.c. of standard being known, the nitrogen of the sample, nitrogen as nitrates, may be easily calculated.

NITROGEN AS NITRITES.—*Solutions required. Sulphanilic Acid:*—0.5 gramme dissolved in 150 c.c. of acetic acid, sp. gr. 1.04. *Alpha-amido-naphthalene acetate:*—0.1 gramme of solid naphthylamine is boiled with 20 c.c. of water, filtered through cotton, and mixed with 180 c.c. of diluted acetic acid. The water used must be free from nitrites.

Process.—To 25 c.c. of the water add 2 c.c. of the sulphanilic acid solution and 2 c.c. of the amido-naphthalene acetate. In presence of nitrites a pink color is produced, the intensity of the color and the rapidity of its development being proportionate to the amount of nitrites present.

HARDNESS OF WATER.—Water may be "temporarily hard"

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from presence of carbonates of calcium or magnesium; it may be "permanently hard" from presence of the sulphates of the same elements. *Hehner's Method; Solutions required—Sodium Carbonate:* —1.06 grammes of recently ignited sodium carbonate are dissolved in 1000 c.c. of water. Each c.c. of this solution is the equivalent of 0.001 gramme of calcium carbonate. *Standard Sulphuric Acid:* —1 c.c. of the strong acid is dissolved in 1000 c.c. of water and tested with the sodium carbonate solution, using lacmoid as the indicator. The sulphuric acid is then diluted until 1 c.c. will exactly neutralize 1 c.c. of the sodium carbonate, each c.c. of the acid solution being thus made equivalent to 0.001 gramme of calcium carbonate.

Process.—For the determination of the *temporory hardness*, 100 c.c. of the water, tinted with lacmoid, are heated just to boiling, and the sulphuric acid added until the color changes. Each c.c. of the acid used represents 0.001 gramme of calcium carbonate in the sample taken.

For the determination of the *permanent hardness*, to 100 c.c. of the water add a measured excess of the sodium carbonate solution, and evaporate to dryness in a platinum dish. Mix the residue with boiling distilled water, filter and titrate the still hot filtrate with the acid. The difference between the number of c.c. of acid used and the number of c.c. of sodium carbonate added gives the permanent hardness in terms of calcium carbonate.

Detection of Metals.—In general, a measured volume of water may be evaporated to a small bulk and examined by the regular scheme (p. 60), remembering the possible presence of phosphates. Arsenic, antimony and mercury may be tested for, also, by special tests. Lead will be precipitated as the brownish-black sulphide on addition of a few drops of ammonium sulphide, the precipitate being insoluble in dilute hydrochloric acid (distinction from iron) and insoluble in potassium cyanide (distinction from copper). Iron may be tested for, directly, by boiling with a drop of strong nitric acid and then adding potassium sulphocyanate, a blood-red color or faint reddish tint indicating iron in large or small amount.

Clinical Tests.—The *Total Solids*, *Volatile Matter*, *etc.*, may be determined as described. *Chlorine* may be easily determined as described, or it may be tested for qualitatively, by merely adding a drop of silver nitrate solution, after first acidulating with nitric acid. *Phosphates* may be tested for as described, or by the follow-

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ing—Heisch's Test: Fill a 100 c.c. flask with the water and add 0.5 gramme of pure crystallized sugar. Cork the flask and let it stand in the sunlight, at a temperature of 27° C., for several hours. A turbidity, due to a growth of micro-organisms, indicates the presence of phosphates.

A large excess of *Ammonium Compounds* may be shown, without previous distillation, by the direct addition of a few drops of Nessler's reagent—a brownish color, or if the ammonium compounds be present in very large amount, a brownish precipitate will be obtained. (Experiment with pure water, with well water, with water to which a drop of very dilute ammonium hydroxide has been added, etc.) *Nitrites*, *Nitrates* and the *Metals* may all be tested for as described. The presence of *Calcium* may be demonstrated by addition to the water of ammonium chloride, ammonium hydroxide and ammonium oxalate. *Sulphates* are shown by adding barium chloride after first acidulating with hydrochloric acid.

Interpretation of Results.

The interpretation of the results of analysis will be governed by the character of the water, whether "surface," "subsoil," "deep well," or "spring," and also by the local conditions as regards soil, cultivation, population, proximity to the sea, etc.

The presence of a marked *Color*, *Odor*, or *Taste*, will at once suggest a contamination more or less serious, but, on the other hand, a water may be perfectly normal in these respects and still may be dangerously polluted. The *Total Solids* carried by natural waters vary greatly in amount; 600 parts per million is generally regarded as the permissible maximum. With an increase in mineral matter the water passes into the category of mineral waters and becomes a medicinal agent. Organic matter of animal origin should be entirely absent, nor should vegetable matter be present in large amount. Not over one-half of the solids should be lost by ignition.

Chlorine, as sodium chloride, is a constituent of many soils and in certain localities, notably near the sea, may be present in considerable amount. In absence of such natural origin, however, chlorine is suggestive of animal pollution, the chlorides being constant and indestructible elements of all sewage and excreta. Unless accounted for by mineral sources, chlorine exceeding 10 parts per million is to be regarded with suspicion.

Phosphates should not exceed 0.6 part per million, phosphates

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like chlorides being characteristic of the excreta. If a marked turbidity, and especially if the odor of butyric acid, develop with the Heisch clinical test (see p. 224), the water is to be regarded as contaminated. Negative results with phosphate tests, however, are not conclusive evidence of freedom from contamination. *Nitrogen of Ammonium and Albuminoid Compounds.* The nitrogen of *ammonium compounds* (the so-called "free-ammonia") is subject to considerable variation, but when in large amount suggests organic contamination. The permissible limit is generally placed at 0.2–0.5 part per million, though, except with certain deep waters, an uncontaminated water does not often average more than 0.04–0.05 part per million. The determination has little value, however, unless considered with the nitrogen of *albuminoid compounds* (the so-called "albuminoid ammonia"). When the nitrogen of albuminoid compounds is less than 0.02 part per million, the water is generally free from organic pollution. If the nitrogen of albuminoid compounds be above 0.05 part per million, and there be a considerable amount of the ammonium compounds, the water may be contaminated; but if the ammonium compounds be low, the water will be acceptable until the albuminoid nitrogen reaches 0.08 part per million, when the chlorine must be taken into account. The *Nitrites* are usually evidence of existing fermentative changes and should be absent. The *Nitrates* represent the final stage in the oxidation of nitrogenous organic compounds, or, they may be derived from the mineral salts of the soil. In general, 5 or 6 parts per million, is regarded as a permissible maximum. The *Hardness* of water is not of sanitary importance unless excessive. It is of interest more especially as regards the use of the water in steam boilers, in the laundry, and for cooking.

It is to be understood that the figures given above are subject to local modification. It is, in fact, impossible to present a set of rigid standards universally applicable; the exact interpretation of a water analysis can only be obtained as a result of experience.

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EXAMPLES OF WATER ANALYSES.

(In parts per million.)

	Total Solids.	Chlorine.	N. of Ammonium Compounds.	N. of Albuminoid Compounds.	N. of Nitrites.	N. of Nitrates.
Rain water,* Bellefonte, Pa.	5.0	Absent.	0.28	0.148	Absent.	Absent.
Schuylkill River Water—						
Muddy *	180.0	——	Absent.	0.180	Trace.	0.25
Filtered	146.0	5.0	0.06	0.090	Absent.	Present.
Distilled	13.0	Absent.	0.086	0.012	Absent.	Absent.
Driven Well, 109 feet. Devon, Pa. *Pure.*	91.0	7.0	0.030	0.014	Absent.	1.2
Driven Well, 75 feet. Philadelphia, Pa. *Contaminated* . . .	330.0	35.4	0.306	0.070	Present.	20.0
Well, Passaic Co., N.J. *Contaminated* . .	709.0	123.0	0.068	0.030	Present.	12.6
Artesian Well,* Philadelphia, Pa. . . .	——	89.21	0.248	0.032	Trace.	Trace.
Spring Water, *Pure*, Haverford, Pa. .	66.0	7.0	0.028	0.024	Absent.	2.8

NOTE.—Analyses marked with asterisk (*) are from Leffmann and Beam, other results are from complete analyses by one of the authors.

The filtered river water is not of the same date as that marked "muddy." The distilled water was obtained by an ordinary continuous distillation on a large scale.

Results in parts per million may be converted into grains per U. S. gallon by multiplying by 0.0584—or into grains per Imperial gallon, multiplying by 0.07.

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APPENDIX.

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POISONS, AND THE TREATMENT OF POISONING.

GENERAL PRINCIPLES OF TREATMENT:

1. *Remove the poison from the stomach.* Wash out the stomach, using a stomach tube, or give emetics, *e. g.*, *zinc sulphate*, *mustard*, *ipecacuanha*, or, hypodermatically, *apomorphine.* Follow with purgatives, *e. g.*, *magnesium sulphate*, *castor oil*, etc.

2. *Administer the chemical antidote.* In poisoning by acids, give *magnesia* in milk or water. In poisoning by alkalies, give dilute *acetic acid* or vinegar, dilute *citric acid* or lemon juice. In poisoning by alkaloids, give a solution of *tannin*, or strong boiled tea. The chemical antidote may advantageously be mixed with the water used in washing the stomach. Milk is very generally helpful. When possible, administer the *special* chemical antidote.

3. *Administer the physiological antidote.* (a) When the pulse is weak, intermittent or slow, sustain the heart by subcutaneous injections of *nitroglycerin*, *strychnine* or *atropine*, or give an enema of *brandy* or of strong coffee. Give inhalations of *amyl nitrite*, or give aromatic spirits of ammonia. *Keep the patient in a recumbent position.*

(b) When the respiration is difficult, keep the *body warm*, apply *cold effusions* to the head, perform *artificial respiration*, resort to *tracheotomy* if necessary, *i. e.*, if the difficulty be due to irremovable obstruction.

(c) When there is coma or insensibility, apply *friction*, flagellation, mustard plasters, or administer excitants, *e. g.*, *strychnine.* Forced walking may be resorted to, but not when the heart is affected.

(d) When there are convulsions, spasms, etc., administer *ether* or *chloroform* by inhalation, give *potassium bromide*, or, subcutaneously, *morphine.* Chloral is not advised. Valerian may be given per rectum.

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SPECIAL SYMPTOMS SUGGESTING CERTAIN COMMON POISONS:

Great pain, cold skin, collapse—*Acids, Alkalies and other Corrosive Irritants.*

Thirst, pain, vomiting, diarrhœa—*Arsenic and other True Irritants.*

Unconsciousness, contracted pupils, congestion—*Morphine and its preparations.*

Unconsciousness, contracted pupils, cold skin—*Phenol* (*Carbolic Acid*). Note odor or stains.

Unconsciousness, dilated pupils, cold skin—*Alcohol* (acute).

Titanic convulsions, opisthotonos—*Strychnine.*

Active delirium, dilated pupils, hot skin—*Atropine* (*Belladonna*). etc.

Numbness, tingling, paralysis—*Aconitine.*

Heart very slow, rapid on movement, with nausea, pain, vertigo, disturbed vision—*Digitalis.*

COMMON REMEDIES USED.

Emetics.—APOMORPHINE HYDROCHLORATE. Hypodermatically. $\frac{1}{10}$ grain (6.5 milligrammes).

COPPER SULPHATE. 10–30 grains (0.6–2.0 grammes).

IPECACUANHA. 20 grains (1.3 grammes).

MUSTARD. 2–8 teaspoonfuls, in 8 ounces of tepid water.

ZINC SULPHATE. 10–30 grains (0.6–2.0 grammes).

Purgatives.—CASTOR OIL. 4–8 fl. drachms (16–32 c.c.).

MAGNESIUM SULPHATE. 1 ounce (31 grammes).

Stimulants.—AMYL NITRITE. For inhalation. 2–4 minims (0.1–0.25 c.c.).

AROMATIC SPIRITS OF AMMONIA. 30–60 minims (2.0–4.0 c.c.).

ATROPINE SULPHATE. Hypodermatically. $\frac{1}{120}$ grain (0.5 milligramme).

BRANDY. For hypodermatic dose, 20–30 minims (1.2–2.0 c.c.).

NITROGLYCERIN. Hypodermatically or by mouth, $\frac{1}{100}$ grain (0.6 milligramme).

STRYCHNINE SULPHATE. Hypodermatically. $\frac{1}{60}$–$\frac{1}{30}$ grain (1.0–2.0 milligrammes).

Sedatives.—CHLORAL. 10–20 grains (0.6–1.3 grammes).

MORPHINE SULPHATE. Hypodermatically. $\frac{1}{4}$ grain (16 milligrammes).

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POTASSIUM BROMIDE. 10–30 grains (0.6–2.0 grammes).

Chemical Antidote for Alkalies.—ACETIC ACID. U. S. P., 36 per cent., diluted with 7 parts of water.

Chemical Antidote for Acids.—MAGNESIA. Give freely in water or in milk.

Chemical Antidotes for Alkaloids.—TANNIC ACID (Tannin). 10–20 grains (0.6–1.3 grammes).

SOLUTION OF IODINE. Dissolve 1 grain (65 milligrammes) of Iodine with 10 grains (0.65 gramme) of Potassium Iodide in 1 fl. ounce (30 c.c.) of water. Divide into 4 doses.

Other Special Remedies are given in the list of poisons which follows.

THE POISONS, WITH LEADING SYMPTOMS AND TREATMENT.

ACETANILIDE. Depressant. *Treatment.*—Emetics, stimulants, brandy, *strychnine*, atropine, *recumbent position.*

ACIDS. (Concentrated.) Violent pain, vomiting, retching, hematemesis, prostration, collapse, possibly asphyxia. *Treatment.*—*Magnesia* in water or milk, flour in milk, demulcent drinks, morphine to allay pain. Hypodermatic stimulants in collapse, food per rectum.

ACIDS. (Dilute.) Similar to concentrated acids, less corrosion, more true inflammation. *Treatment.*—Stomach tube, emetics, *magnesia* in milk, barley water, etc.

ACONITINE. Numbness, tingling, deafness, dimness of vision, paralysis, heart and respiration depressed. *Treatment.*—Stomach tube, emetics, nitroglycerin, *atropine*, or *strychnine* hypodermatically, brandy enema, inhalation of amyl nitrite, *recumbent position*, warmth to body.

ALCOHOL. (Spirits, etc.) Acute poisoning. Dyspnœa, dilated pupils, convulsions, stupor, coma. *Treatment.*—Stomach tube, emetics, cold affusion to head, inhalation of amyl nitrite, strong coffee, fresh air, *warmth* to body, *strychnine.*

ALKALIES. (*Caustic, concentrated.*) Similar to concentrated acids, q. v. (Test reaction of vomited matter.) *Treatment.*—Give plenty of water and follow with *dilute acids*, *acetic*, *citric*, etc., *olive oil*, white of egg, gruel, barley water, emetics, morphine to allay pain, hypodermatic stimulants, food per rectum.

ALKALIES. (*Dilute.*) Similar to dilute acids, q. v. *Treatment.*

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—Stomach tube, emetics, *dilute acetic acid*, *vinegar*, *lemon juice*, demulcent drinks.

ALUM. In large doses an irritant. *Treatment.*—Stomach tube, emetics, magnesia, weak solution of ammonium carbonate.

AMMONIA. The fumes cause laryngeal spasms, coughing, etc. *Treatment.*—Inhalation of *acetic acid vapor*, or of chloroform. Otherwise ammonia is similar to other Alkalies, q. v.

AMYL NITRITE. A vaso-dilator, lowers blood-pressure; headache, throbbing vessels, etc. *Treatment.*—Fresh air, strychnine or atropine hypodermatically, picrotoxin, recumbent position.

ANTIMONY. (Tartar emetic.) Nausea, retching, vomiting, pain, purging, general depression. *Treatment.*—Stomach tube if necessary, solution of *tannin* or strong tea, *white of eggs*, in collapse strychnine hypodermatically, brandy enema, keep body warm.

ANTIMONY CHLORIDE. Similar to acids, q. v.

ANTIPYRINE. See Acetanilide.

ARNICA. An irritant. *Treatment.*—Emetics, alcoholic stimulants, etc.

ARSENIC. Thirst, burning pain, vomiting, purging, cramps, skin cold, pulse small. *Treatment.*—Stomach tube, emetics, milk with white of egg, magnesium sulphate, *magnesia*, *dialyzed iron*. Keep body warm, and, if necessary, relieve pain with morphine. *Special antidote:* Freshly precipitated *ferric hydroxide*. Add ammonium hydroxide (or sodium carbonate) to an aqueous solution of ferric chloride, filter through a handkerchief, wash with water, and administer in teaspoonful doses.

ATROPINE. (Belladonna.) Face flushed, pupils dilated, eyes prominent, contraction of pharynx, excitement, delirium. *Treatment.*—Emetics, *pilocarpine nitrate* ($\frac{1}{4}$–$\frac{1}{2}$ grain), morphine, coffee enema. Hot bags at feet, and, if necessary, artificial respiration.

BARIUM SALTS. Irritants; pain, vomiting, etc. *Treatment.*—Stomach tube, emetics, magnesium sulphate, sodium sulphate, mucilaginous drinks.

BELLADONNA. See Atropine.

BICHLORIDE OF MERCURY. See Mercury.

BROMIDES. Depressants. *Treatment.*—Wash out stomach and give stimulants, atropine, strong coffee, etc.

BROMINE.—Spasmodic action of larynx and pharynx, burning pain, tremor and collapse. *Treatment.*—As under Iodine, q. v. When bromine vapor has been inhaled, give inhalations of very dilute ammonia.

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BRUCINE. Similar to Strychnine, q. v.

CALABAR BEAN. See Physostigmine.

CAMPHOR. In large doses a cerebral poison. *Treatment.*—Stomach tube, emetics, brandy hypodermatically or as an enema. Keep body warm.

CANTHARIDIN. Blisters, burning pain, dull pain in loins, urine bloody, genito-urinary inflammation. *Treatment.*—Stomach tube, apomorphine, magnesium sulphate, morphine, stimulants, demulcent drinks, gum arabic and water; do not give oils.

CARBOLIC ACID. (Phenol.) Faintness, pallor or lividity, pupils contracted, feeble pulse, stertorous breathing, coma, urine darkens on exposure, odor of breath. *Treatment.*—Stomach tube to be used very cautiously. Zinc sulphate, *sodium sulphate* or *magnesium sulphate*, white of eggs, atropine, brandy, inhalation of amyl nitrite, *dilute acetic acid* or *diluted vinegar*, keep body warm.

CASTOR SEEDS. Purging, thirst, convulsions. *Treatment.*—Tannin or strong tea, morphine for the pain and tenesmus, keep extremities warm, and give stimulants.

CHLORAL. Local irritation, heart depressed, coma. *Treatment.*—Stomach tube, emetics, atropine or strychnine, brandy or coffee enema, amyl nitrite, artificial respiration if necessary, body warm.

CHLOROFORM. (*Inhaled.*) *Treatment.*—Artificial respiration, rhythmic traction of tongue, oxygen, cold effusions, galvanism, stimulants, amyl nitrite, strychnine.

CHLOROFORM. (*Internal.*) Burning pain, possibly vomiting, insensibility, weak pulse, dilated pupils, stertorous breathing. *Treatment.*—Stomach tube, emetics, enema of coffee, amyl nitrite, artificial respiration.

CHROMIUM SALTS. Vomiting, diarrhœa, etc. *Treatment.*—Stomach tube, emetics, magnesia, barley water, etc.

COCAINE. Faintness, dizziness, weak pulse, delirium or coma, sometimes paralysis. *Treatment.*—Stomach tube, emetics, fresh air, tea, tannin, amyl nitrite, oxygen.

COCCULUS INDICUS. Nausea, debility, possibly convulsions. *Treatment.*—Stomach tube, emetics, chloral, potassium bromide.

COLCHICUM. Thirst, vomiting, purging, exhaustion, cramps. *Treatment.*—Stomach tube, tannin or tea, body warm, stimulants. Morphine for pain and tenesmus.

COLOCYNTH. Similar to colchicum, q. v.

CONIUM. (Hemlock.) Weakness, staggering, paralysis. *Treat-*

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ment.—Stomach tube, apomorphine, tannin, strychnine, stimulants, coffee, artificial respiration.

COPPER SALTS. Vomiting, purging, pain. *Treatment*—Apomorphine if necessary; *warm milk with white of egg*, magnesia, *potassium ferrocyanide.*

CORROSIVE SUBLIMATE. See Mercury.

CREOSOTE. See Carbolic Acid.

CROTON OIL. Intense pain, vomiting, purging, collapse. *Treatment.*—Wash with stomach tube, demulcent drinks, brandy, stimulants, *camphor spirits* 10 drops on sugar every ten minutes, keep body warm, *morphine* for pain and tenesmus.

CYANIDES. Similar to Prussic acid, q. v.

DIGITALIS. In large doses, pain, vomiting, "blue vision," headache, vertigo, paralysis of heart. *Treatment.*—Emetics, tannin, morphine, *nitroglycerin*, *amyl nitrite*, aconitine ($\frac{1}{800}$ grain), *senega* (15 grains), *recumbent position.* Stimulants, brandy, etc., cautiously.

ELATERIUM.. Similar to Colchicum, q. v.

ERGOT. In large doses acts as irritant, and, indirectly, on heart. *Treatment.*—Zinc sulphate as emetic, tannin, tea, nitroglycerin, amyl nitrite, aconitine ($\frac{1}{800}$ grain), friction, keep body warm.

ETHER. Internally acts as an irritant and produces intoxication. Inhaled is similar to chloroform, though not so depressing. *Treatment.*—See Chloroform.

FORMALDEHYDE. (Formalin.) Vomiting, pain. *Treatment.*—White of egg, stomach tube, emetics, dilute ammonia by inhalation, *ammonium acetate internally.*

FUSEL OIL. (Amyl alcohol.) Headache, nausea, prostration, coma. *Treatment.*—See Alcohol.

GASES. (Asphyxia.) Loss of muscular power, insensibility, labored breathing. *Treatment.*—Artificial respiration, fresh air, oxygen, ozone, friction, brandy hypodermatically or as an enema.

GELSEMIUM. (Gelsemine.) Pain in eyes, disturbed vision, weakness, pain in chest, difficult respiration. *Treatment.*—Stomach tube, emetics, electricity, atropine, nitroglycerin, artificial respiration.

HEMLOCK: Cicuta maculata (Water Hemlock), vomiting, pain, violent convulsions. (Conium maculatum. See Conium.) *Treatment.*—Emetics, chloral, chloroform, etc.

HYDROCHLORIC ACID. See Acids.

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HYDROCYANIC ACID. See Prussic Acid.

HYOSCYAMINE. Similar to Atropine, q. v.

IGNATIA. Similar to Strychnine, q. v.

IODINE. Pain, vomiting, purging, full, rapid pulse, eruption on skin. *Treatment.*—Emetics, *boiled starch and water*, boiled flour paste and water, amyl nitrite, morphine for pain.

IODIDES. Often produce catarrhal symptoms, voice reduced, little pain. Otherwise similar to Iodine. *Treatment.*—Stomach tube, emetics, atropine.

IODOFORM. Anorexia, depression or excitement, rapid pulse, high temperature, collapse. *Treatment.*—Remove cause, and treat symptoms.

JABORANDI. See Pilocarpine.

LAUDANUM. See Morphine.

LEAD SALTS. (*Acute.*) Nausea, burning in stomach, colic relieved by pressure, retching. *Treatment.*—Stomach tube and emetics. *Magnesium sulphate, sodium sulphate*, potassium iodide.

(*Chronic.*) Anæmia, fetid breath, colic, constipation, "wrist drop," palsy. *Treatment.*—Remove cause, and nourish.

LOBELIA. Motor depressant, narcotic, emetic. *Treatment.*—Stomach tube, brandy, atropine, strychnine.

MERCURY. (Corrosive sublimate.) Painful constriction of throat, burning pain, purging, evacuations show mucus and blood, cold perspiration, faintness, convulsions. *Treatment.*—Promote vomiting, *white of egg in milk, followed by stomach tube or emetics*, gelatin, magnesia, alkaline carbonates, morphine for pain.

MORPHINE. (Opium, etc.) Brief excitement, then weight in limbs, drowsiness, sleep, coma, pupils contracted, labored breathing, feeble pulse, skin generally warm, muscles flabby in bad cases. *Treatment.—Stomach tube*, emetics, *atropine, potassium permanganate* (10 grains in water), coffee as enema, keep body warm, amyl nitrite inhalations, cold affusions, faradization.

MUSHROOMS. (Poisonous fungi.) *Amanita muscaria* (Fly fungus). Heart's action retarded, difficult breathing, stupor, cold sweat, convulsions. *Treatment.*—Stomach tube, *emetics*, castor oil, *atropine* ($\frac{1}{100}$ to $\frac{1}{50}$ grain), stimulants and warmth.

Amanita phalloides. (Death cup.) Pain, nausea, vomiting, purging, otherwise similar to A. muscaria. *Treatment.*—Rarely satisfactory, stimulants, etc., physiological salt solution subcutaneously may help. Give emetics and atropine.

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NICOTINE. (Tobacco.) Acts on heart and respiratory centers. *Treatment.*—Emetics if necessary, tannin, brandy, *strychnine*, *recumbent position* and warmth.

NITROBENZENE. Similar to Prussic acid, but with more nausea. *Treatment.*—Same as for Prussic acid.

NUX VOMICA. See Strychnine.

OPIUM. See Morphine.

OXALIC ACID. Similar to Acids, q. v., with addition of depression of heart, and other neurotic symptoms. *Treatment.*—As for Acids, lime water is excellent; do not use salts of alkalies.

PHENACETINE. Similar to Acetanilide.

PHENOL. See Carbolic acid.

PHOSPHORUS. Disagreeable taste, thirst, nausea, vomiting, purging, later a jaundiced condition and hemorrhages, sometimes neurotic symptoms, cramps, convulsions. *Treatment.*—*Copper sulphate*, magnesia in mucilaginous drinks, magnesium sulphate, animal charcoal, *dilute hydrogen dioxide*, inhalation of oxygen or ozone. Old oil of turpentine, but no other oils.

PHYSOSTIGMINE OR ESERINE. (Calabar bean.) Prostration, paralysis of lower limbs, pupils contracted, asphyxia. *Treatment.*—Emetics, tannin, *atropine*, strychnine, artificial respiration.

PICROTOXIN. (Cocculus indicus.) Nausea, debility, may be convulsions. *Treatment.*—Remove poison, potassium bromide, chloral.

PILOCARPINE. Profuse secretions, temperature low, heart quickened, paralysis of heart. *Treatment.*—Emetics, tannin, *atropine*, warmth.

PODOPHYLLUM. Irritant cathartic. *Treatment.*—See Colchicum.

POTASH. (Caustic.) See Alkalies.

POTASSIUM CHLORATE. Vomiting, diarrhœa, hemoglobinuria. *Treatment.*—Same as for Potassium nitrate.

POTASSIUM CYANIDE. Similar to Prussic acid, q. v.

POTASSIUM NITRATE. (Nitre.) Pain, vomiting, possibly convulsions, or paralysis. *Treatment.*—Stomach tube, apomorphine, water, amyl nitrite.

PRUSSIC ACID. (Hydrocyanic acid.) Vertigo, loss of muscular power, loss of consciousness, eyes fixed, pupils large, skin cold, convulsive breathing. *Treatment.*—Stomach tube, emetics, atropine, brandy, body warm, cold affusions to neck, artificial respiration. Wash stomach with dilute *hydrogen dioxide* and use the same, also, subcutaneously. Chlorine water, ½ oz. well diluted.

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PTOMAINES. Gastric and intestinal irritation, with extreme prostration. *Treatment.*—Stomach tube, emetics, castor oil, tea, tannin, morphine. Lime water with creosote for the nausea. (Give 1 fluid drachm of a mixture of lime water, 1 ounce, creasote, 3 minims.) Capsicum tincture, 10–20 minims, solution ammonium acetate 1–2 fluid drachms, vinegar and water, strong black coffee.

PULSATILLA. Irritant and depressant. *Treatment.*—Stomach tube, emetics, brandy, digitalis.

RHUS TOXICODENDRON. Stimulant narcotic, and irritant. *Treatment.*—Internal poisoning. Emetics, demulcents, and alkalies, tea, coffee. External poisoning. Apply lotion of lead acetate, 2 drachms, and ammonium chloride, 4 drachms, in 8 fluid ounces of water.

SAVIN. Irritant and abortifacient. *Treatment.*—Emetics, Epsom salts, demulcent drinks, morphine, etc.

SILVER NITRATE. (Lunar caustic.) An irritant. *Treatment.*—Stomach tube, emetics, *sodium chloride* freely in water, demulcent drinks.

SNAKE POISONS. Local irritants, with heart and respiratory symptoms. *Treatment.*—Suck wound, ligature, wash with solution of permanganate, or, better, with a fresh solution of calcium hypochlorite, inject hypochlorite around wound. The hypochlorite solution is made by dissolving one part dry hypochlorite of lime in eleven parts of water. Hypodermatic dose, 1–2 c.c., with a total of 20 c.c. Artificial respiration, stimulants, brandy, keep body warm.

SODA. (Caustic.) See Alkalies.

SOLANINE. Similar to Atropine, q. v.

STAPHISAGRIA. (Larkspur.) Irritant. *Treatment.*—Plenty of water, emetics, tannin, sedatives, warmth to extremities.

STRAMONIUM. Similar to Atropine, q. v.

STROPHANTHUS. Resembles digitalis, q. v.

STRYCHNINE. Restlessness, shuddering, twitching, then tetanic convulsions generally with opisthotonos, followed by periods of relaxation. *Treatment.*—Emetics, stomach tube with plenty of water, tannin, inhalation of ether, 1 drachm doses of *potassium bromide*, nitroglycerin or amyl nitrite. Keep patient in darkened room and avoid excitement.

SULPHONAL, TRIONAL, etc. In sufficient dose, coma and convul-

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sions, urine dark red. *Treatment.*—Wash stomach with water containing a little sodium carbonate. Spirits of nitrous ether 1 drachm doses, magnesium sulphate 1 ounce doses.

SULPHURIC ACID. See Acids.

TARTAR EMETIC. See Antimony.

TOBACCO. See Nicotine.

VERATRUM. Pain, retching, vomiting, purging, vertigo, weak heart and pulse. *Treatment.*—Promote vomiting if necessary, brandy or coffee enema, keep body warm and in recumbent position.

ZINC SALTS. Pain, vomiting, purging, etc. *Treatment.*—Emetics if necessary, white of egg in milk, tea, tannin, magnesium sulphate, soap, magnesia in water or milk.

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WEIGHTS AND MEASURES.

1 milligramme	=	0.001 gramme	= 0.01543 grain, Troy.
1 centigramme	=	0.010 "	
1 decigramme	=	0.100 "	
1 gramme	=	1.000 "	= 15.43235 grains, Troy.
1 decagramme	=	10.000 grammes.	
1 hectogramme	=	100.000 "	
1 kilogramme	=	1000.000 "	= 2.6790 pounds, Troy.
1 kilogramme			= 2.2046 pounds, Av.
1 tonneau	=	1000.000 kilogrammes.	

TROY WEIGHT.

Pound.	Ounces.	Pennyweights.	Grains.		Grammes.
1	12	240	5760	=	373.2419
	1	20	480	=	31.1035
		1	24	=	1.5552

APOTHECARIES' WEIGHT.

Pound.	Ounces.	Drachms.	Scruples.	Grains.		Grammes.
1	12	96	288	5760	=	373.2419
	1	8	24	480	=	31.1035
		1	3	60	=	3.8879
			1	20	=	1.2959
				1	=	0.0648

One Apothecaries' ounce of water contains 504.829 minims.

AVOIRDUPOIS WEIGHT.

Pound.	Ounces.	Drachms.	Grains.		Grammes.
1	16	256	7000	=	453.5926
	1	16	437.5	=	28.3495
		1	27.343	=	1.7718

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GRAMMES AND GRAINS.

Grammes.		Grains.	Grains.		Grammes.
1	=	15.43235	1	=	0.06479
2	=	30.86470	2	=	0.12958
3	=	46.29705	3	=	0.19437
4	=	61.72940	4	=	0.25916
5	=	77.16175	5	=	0.32395
6	=	92.59410	6	=	0.38874
7	=	108.02645	7	=	0.45353
8	=	123.45880	8	=	0.51832
9	=	138.89115	9	=	0.58311

MEASURES OF CAPACITY.

1 millilitre = 1 cubic centimetre	=	0.061027	cubic inch.
	=	0.033816	U. S. fluid ounce.
	=	16.2310	U. S. minims.
1 litre = 1000 cubic centimetres	=	33.816	U. S. fluid ounces.
	=	35.219	Imperial.
	=	1.0567	U. S. quart.
1 kilolitre = 1000 litres	=	264.18	U. S. gallons.

APOTHECARIES' OR WINE MEASURE (U. S.)

Gallon.	Pints.	Fluid Ounces.	Fluid Drachms.	Minims.	Cubic Centimetres.
1	8	128	1024	61440 =	3785.432
(58418.14 grains)	1	16	128	7680 =	473.179
		1	8	480 =	29.574
			1	60 =	3.696
				1 =	0.0616

One fluidounce of water weighs 456.392 grains.
One pint of water weighs 7302.27 grains.

APPROXIMATE EQUIVALENTS AUTHORIZED BY THE U. S. P.

4 c.c. = 1 fluidrachm = 1 teaspoonful.
8 c.c. = 2 fluidrachms = 1 dessertspoonful.
16 c.c. = 4 fluidrachms = 1 tablespoonful.

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IMPERIAL MEASURE.

Gallon.	Pints.	Fluid Ounces.	Fluid Drachms.	Minims.	Cubic Centimetres.
1	8	160	1280	76800 =	4543.487
(70,000 grains)	1	20	160	9600 =	567.936
		1	8	480 =	28.396
			1	60 =	3.549
				1 =	0.059

MEASURES OF LENGTH.

1 millimetre = 0.001 metre = 0.03937 inch.
1 centimetre = 0.010 "
1 decimetre = 0.100 "
1 metre = 1.000 " = 3.28089 feet.
1 decametre = 10.000 metres.
1 hectometre = 100.000 "
1 kilometre = 1000.000 " = 0.62138 mile.

1 inch = 2.53995 centimetres.
1 foot = 0.30479 metre.
1 yard = 0.91438 metre.
1 mile = 1.60931 kilometres.

MEASURES OF TEMPERATURE.

	Water boils.	Water freezes.
Centigrade	100°	0°
Fahrenheit	212°	32°
Reaumur	80°	0°

To convert °C to °F, multiply by 9, divide by 5, and add 32.

To convert °F to °C, subtract 32, multiply by 5, and divide by 9.

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THE PREPARATION OF PERCENTAGE SOLUTIONS.

To make one pint of a—

$\frac{1}{500}$ per cent. solution,	(1 in 5000,)	dissolve	$1\frac{1}{2}$ grains.
$\frac{1}{200}$ per cent. solution,	(1 in 2000,)	dissolve	$2\frac{3}{8}$ grains.
$\frac{1}{100}$ per cent. solution,	(1 in 1000,)	dissolve	$7\frac{1}{3}$ grains.
$\frac{1}{4}$ per cent. solution,	(1 in 400,)	dissolve	$18\frac{1}{4}$ grains.
$\frac{1}{2}$ per cent. solution,	(1 in 200,)	dissolve	$36\frac{1}{2}$ grains.
1 per cent. solution,	(1 in 100,)	dissolve	73 grains.
2 per cent. solution,	(1 in 50,)	dissolve	146 grains.
4 per cent. solution,	(1 in 25,)	dissolve	292 grains.
5 per cent. solution,	(1 in 20,)	dissolve	365 grains.
10 per cent. solution,	(1 in 10,)	dissolve	730 grains.

To form a mixture of certain percentage from two solutions of different percentages. The difference between the percentage desired and the percentage of one of the solutions, will give the amount of the other solution to be included in the mixture. *Example.*—Required the proportionate amounts of two solutions, containing 7 and 18 per cent. respectively, to make a mixture containing 16 per cent.

18 — 16 = 2 parts of the 7 per cent. solution.
16 — 7 = 9 parts of the 18 per cent. solution.

DILUTION OF ALCOHOL. A = Percentage strength of the stronger alcohol; B = Percentage strength desired. Add to B parts of the stronger alcohol, sufficient water to make A parts of the more dilute. *Example.*—To make 30 per cent. alcohol from 94 per cent. alcohol, add to 30 parts of the 94 per cent. alcohol sufficient water to make in all, 94 parts.

To make a definite quantity of the weaker alcohol: Multiply the required strength by the required amount, and divide by the percentage of the alcohol given. The result equals the amount of stronger alcohol to be diluted. *Example.*—To make 100 c.c. of 30 per cent. alcohol from 94 per cent. alcohol: Multiply 30 by 100 and divide by 94; the result (31.9) equals the number of c.c. of the 94 per cent. alcohol to be diluted.

To convert all of a certain quantity to another percentage: Multiply the quantity of alcohol by its percentage strength and divide by the required percentage. The quotient gives the quantity *to*

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which the alcohol must be diluted. *Example.*—To dilute 500 c.c. of 94 per cent. alcohol to 87 per cent. Multiply 500 by 94 and divide by 87. The quotient 540 gives the number of c.c. to which the alcohol is to be diluted—*i. e.*, 40 c.c. of water are to be added.

The Common Acid Radicals.

1. *Monobasic.*—Acetate, $C_2H_3O_2$; benzoate, $C_7H_5O_2$; bromide, Br; chlorate, ClO_3; chloride, Cl; cyanate, CNO; cyanide, CN; fluoride, F; hypobromite, BrO; hypochlorite, ClO; hypophosphite, H_2PO_2; iodide, I; lactate, $C_3H_5O_3$; metaborate, BO_2; metaphosphate, PO_3; nitrate, NO_3: nitrite, NO_2; perchlorate, ClO_4; salicylate, $C_7H_5O_3$; sulphocyanate, CNS.

2. *Dibasic.* — Carbonate, CO_3; chromate, CrO_4; dichromate, Cr_2O_7; metasilicate, SiO_3; molybdate, MoO_4; oxalate, C_2O_4; persulphate, S_2O_8; phosphite, HPO_3; pyro(or tetra)borate, B_4O_7; sulphate, SO_4; sulphide, S; sulphite, SO_3; silicofluoride, SiF_6; tartrate, $C_4H_4O_6$; thiosulphate, S_2O_3 = "hyposulphite" of pharmacy; tungstate, WO_4.

3. *Tribasic.*—Arsenate, AsO_4; arsenite, AsO_3; borate, BO_3; citrate, $C_6H_5O_7$; ferricyanide, $Fe(CN)_6$; phosphate, PO_4.

4. *Tetrabasic.* — Ferrocyanide, $Fe(CN)_6$; orthosilicate, SiO_4; pyrophosphate, P_2O_7.

Construction of Formulæ.—The acid formulæ may be obtained from the above by prefixing H atoms, the number so prefixed being determined by the basicity, *e. g.* Hypochlorous acid = HClO. Thiosulphuric acid = $H_2S_2O_3$. Orthosilicic acid = H_4SiO_4.

Formulas for the salts may be readily made, remembering that monads combine with monads, dyads with dyads, or with two monads, etc., *e. g.* To determine the formulæ for sodium salicylate, potassium sulphite, and calcium phosphate.

Sodium is univalent, the salicylate radical is univalent (monobasic), hence one sodium atom unites with one salicylate radical, giving the formula $NaC_7H_5O_3$.

Potassium is univalent, the sulphite radical is bivalent (dibasic), hence two potassium atoms unite with one sulphite radical, giving the formula K_2SO_3.

Calcium is bivalent, the phosphate radical is trivalent (tribasic), hence three calcium atoms unite with two phosphate radicals, giving the formula $Ca_3(PO_4)_2$.

Solubilities of Common Salts.

Group I. Pb, Hg(ous), Ag. *Soluble in Water.*—Nitrates, and nitrites of all. Ag, Pb; acetates. Pb; chloride (in hot water).

Insoluble in Water, Soluble in Acids.—Carbonates, oxalates, oxides,

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phosphates, sulphides, tartrates, of all. Ag, Hg; sulphates.* Ag; bromide. Pb; iodide.* Hg; iodide.

Insoluble in Water and Acids.—Ag; chloride, cyanide, iodide. Pb; chromate,† sulphate.† Hg; chloride.†

GROUP II (*a*). As, Sb, Sn. *Soluble in water.*—As; arsenates and arsenites of alkalies, chloride and iodide (decomposed by hot water). Sb; chloride (decomposed by excess of water), tartrate. Sn(ous); chloride, sulphate. Sn(ic); chloride.

Insoluble in Water, Soluble in Acids. As; arsenates and arsenites of metals other than alkalies, oxide,* sulphide. Sb; oxide, sulphide. Sn; oxide, sulphide. Sn(ic); oxide.†

GROUP II (*b*). Hg(ic), Cu, Bi, Cd. *Soluble in Water.*—Acetates, chlorides, nitrates, sulphates, of all. (Bi; chloride and nitrate decomposed by excess of water,) Cu(ous), Cd; iodides.

Insoluble in Water, Soluble in Acids.—Carbonates, oxides, phosphates, sulphides, of all. Bi; oxychloride, oxynitrate, sub-carbonate.

Insoluble in Water and Acids.—Cu; ferrocyanide. Hg; oxysulphate.†

GROUP III. Fe, Cr, Al. *Soluble in Water.*—Acetates, chlorides, nitrates, sulphates, of all. Fe, Al; citrates. Fe(ic), Cr, Al; tartrates. Fe(ous); iodide. Fe(ic); ferricyanide, hypophosphite,* pyrophosphate (in "scale preparations"). Cr; chromates and dichromates of alkalies.

Insoluble in Water, Soluble in Acids.—Arsenates, carbonates, hydroxides, oxides, phosphates, sulphides, of all. Fe(ous); tartrate.

Insoluble in Water and Acids.—Fe; ferrocyanide. Fe(ous); ferricyanide. Cr; oxide.† Al; oxide,† silicate.†

GROUP IV. Mn, Zn, Ni, Co. *Soluble in water.*—Acetates, chlorides, nitrates, sulphates, of all: Ni, Co; citrates, Co; tartrate. Zn; chloride, iodide, valerate. Mn; manganates and permanganates of the alkalies. *Insoluble in Water, Soluble in Acids.*—Arsenates, carbonates, hydroxides, oxides, phosphates, sulphides, of all. Zn; phosphide.

GROUP V. Ca, Ba, Sr, Mg. *Soluble in Water.*—Acetates, bromides, chlorates, chlorides, iodides, nitrates, of all. Ba, Sr, Ca; hydroxides,* oxides,* sulphides. Ca; chromate,* citrate,* hypophosphite, sulphate.* Mg; chromate. citrate, sulphate.

* Sparingly soluble in water. † Sparingly soluble in acids.

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Insoluble in Water, Soluble in Acids.—Ba, Ca, Sr; carbonates, oxalates, phosphates. Mg; carbonate.* Ba, Sr; chromates, sulphites. Mg; hydroxide,* oxide.* Ba; dioxide (with decomposition).

Insoluble in Water and Acids.—Ba, Sr; sulphates.*

GROUP V. K, Na, Li, NH_4. *Soluble in Water.*—Li; benzoate, bicarbonate, bromide, chloride, oxide, salicylate, sulphate. K, Na; acetates, arsenates, arsenites, bicarbonates, bisulphites, borates, carbonates, chlorates, cyanides, hydroxides. hypochlorites, hypophosphites, iodides, nitrates, nitrites, oxides, phosphates, pyrophosphates, silicates, sulphates, sulphides, sulphites, thiosulphates (hyposulphite of U. S. P.), NH_4, bromide, carbonate, chloride, iodide, nitrate, sulphate, sulphide.

(Note.—All common salts of alkalies, except those named below, are soluble in water.)

Insoluble in Water, Soluble in Acids.—K, NH_4; acid tartrates,* platinic chlorides.* K; perchlorate.* Na; antimonate. Li; carbonate, phosphate.*

LIST OF REAGENTS.‡

Acid,§ Acetic, $HC_2H_3O_2$. Sp. gr. 1.04, 30 p. c.; U. S. P. acid,
" strong, sp. gr. 1.045, 36 p. c.; U. S. P. dilute, sp. gr. 1.009, 6 p. c. Glacial Acetic acid, 99 p. c., sp. gr. 1.049.
" Hydrochloric, HCl. U. S. P. strong, sp. gr. 1.158, 31.9 p. c.; U. S. P. dil., sp. gr. 1.049, 10 p. c.
" Hydrosulphuric, H_2S. A gas, by action of FeS on HCl.
" Nitric, HNO_3. Sp. gr. 1.24, 32 p. c.; U. S. P. strong, sp. gr. 1.403, 68 p. c.; U. S. P. dil., sp. gr. 1.054, 10 p. c. "Yellow Nitric" acid, called, also, Nitrous Acid, contains NO_2 in solution.
" Nitrohydrochloric, $NOCl + Cl_2$. 180 c.c. U. S. P. strong HNO_3 with 820 c.c. strong HCl.
" Oxalic, $H_2C_2O_4$. 1 part crystals in 10 parts water (1–10).
" Phosphoric, H_3PO_4. U. S. P. strong, sp. gr. 1.707, 85 p. c.; U. S. P. dil., sp. gr. 1.057, 10 p. c.

* Sparingly soluble in water. † Sparingly soluble in acids.

‡ Certain special reagents will be found described in the text with the tests in which they are used.

§ U. S. P. acids, percentage by weight, specific gravity at 25° C.

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Acid, Picric, $C_6H_2(NO_2)_3OH$. (1 in 100).

" Salicylic, $HC_7H_5O_3$. Powder, or in aqueous solution.

" Sulphanilic, $C_6H_4NH_2SO_3H$. See pages 189 and 222.

" Sulphuric, H_2SO_4. U. S. P. strong, sp. gr. 1.826, 92.5 p. c.; dilute, sp. gr. 1.067, 10 p. c.

" Tannic, $HC_{14}H_9O_9$. Dissolve 10 grammes in 10 c.c. of alcohol, and add water to 100 c.c.

" Tartaric, $H_2C_4H_4O_6$. (1 in 3.)

" Trichloracetic, $HC_2Cl_3O_2$. Crystals.

Acidulated Brine. 500 c.c. of saturated NaCl solution, 30 c.c. HCl.

Alcohol, C_2H_5OH. U. S. P. 94.9 p. c. by vol., 92.3 p. c. by weight, sp. gr. about 0.816 at 15.6° C. (60° F.)

" *Absolute.* Not less than 99 p. c. by weight. Place ordinary alcohol in a flask with quick-lime, and after standing several days distil off at as low a temperature as possible.

Almen-Nylander's Reagent. (Nylander's.) $BiONO_3$, 2 grammes; $NaKC_4H_4O_6$, 4 grammes; NaOH, 8 grammes; water; 100 c.c. The solution should be heated to boiling, cooled, filtered, and preserved in an amber colored bottle.

Ammonium Carbonate, $NH_4HCO_3.NH_4NH_2CO_2$. Dissolve 20 grammes in a mixture of 20 c.c. ammonia water and 70 c.c. water, then add water to 100 c.c.

" Chloride, NH_4Cl. (1 in 10.)

" Hydroxide, NH_4OH. Ammonia Water, U. S. P. sp. gr. 0.958, 10 p. c. NH_3; "Stronger Ammonia," sp. gr. 0.897, 28 p. c.

" Molybdate, $(NH_4)_2MoO_4$. 15 grammes dissolved in 100 c.c. of hot water, with addition of a little ammonium hydroxide if necessary, added gradually to 100 c.c. nitric acid (sp. gr. 1.403). Heat gently for 2 hours.

" Oxalate, $(NH_4)_2C_2O_4.H_2O$. (1 in 25.)

" Sulphate, $(NH_4)_2SO_4$. Saturated aqueous solution.

" Sulphydrate, NH_4HS. Ammonium hydroxide saturated with hydrosulphuric acid.

" Sulphide, $(NH_4)_2S$. Add $\frac{2}{3}$ volume of ammonium hydroxide to one volume of sulphydrate.

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Barfoed's Reagent. Dissolve 10 grammes of pure copper acetate in 150 c.c. water, and add 4.5 c.c, U. S. P. acetic acid.

Barium Carbonate, $BaCO_3$. Solid.

" Chloride, $BaCl_2.2H_2O$. (1 in 10.)

" Hydroxide, $Ba(OH)_2.8H_2O$. Saturated aqueous solution.

" Mixture. Two volumes of saturated solution of barium hydroxide with one volume of saturated solution of barium chloride.

" Nitrate, $Ba(NO_3)_2$. (1 in 10.)

Bismuth Subnitrate, $BiONO_3.H_2O$. Powder.

Bleaching Powder, $CaOCl_2$.

Boas' Reagent. Pure resorcin, 5 grammes; Cane sugar, 3 grammes; dilute alcohol, 100 c.c.

Bromine Water, Br. Aqueous solution of bromine. (1 in 100.)

Calcium Chloride, $CaCl_2.6H_2O$. (1 in 10.)

" Hydroxide, $Ca(OH)_2$. Saturated aqueous solution.

" Sulphate, $CaSO_4.2H_2O$. Finely pulverized and agitated with water for 12 hours and then decanted.

Carbol-Fuchsin, see p. 192.

Carbon Dioxide, CO_2. By action of HCl on $CaCO_3$.

" Disulphide, CS_2. Pure.

Chlorine Water, Cl. Aqueous solution of chlorine. See p. 22.

Chlorinated Soda, for Urea Test. 25 c.c. solution of chlorinated soda with 1 gramme of potassium bromide.

Chloroform, $CHCl_3$. Sp. gr. not below 1.476 at 25°. Boils at 60° to 61° C.

Cobaltous Nitrate, $CO(NO_3)_2.6H_2O$. (1 in 10.)

Cochineal. (Indicator.) Macerate 1 gramme for several days with 20 c.c. alcohol and 60 c.c. water. Filter.

Collodion. 40 grammes of pyroxylin in a mixture of ether 750 c.c. and alcohol 250 c.c.

Congo-red Paper. Prepared by soaking unsized paper in 1 p. c. aqueous solution of Congo-red.

Copper Sulphate, $CuSO_4.5H_2O$. (1 in 10.)

Cupric Ammonium Hydroxide. Solution of $Cu(OH)_2$ in ammonium hydroxide.

" " Sulphate. To a solution of copper sulphate add dilute ammonium hydroxide until the precipitate first formed is nearly but not completely redissolved, then filter.

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Ehrlich's triple stain. See p. 203.

Esbach's Reagent. Picric Acid, 10 grammes; Citric Acid, 20 grammes; Water to 1000 c.c.

Ether, $(C_2H_5)_2O$. U. S. P. sp. gr. 0.716–0.717, 96 p. c. Boils at 35.5° C.

Fehling's Solution. Prepared in 2 parts. I. 34.639 grammes of pure crystallized $CuSO_4$, dissolved in water and diluted to 500 c.c. II. 173 grammes Rochelle salt and 60 grammes NaOH, dissolved in water and diluted to 500 c.c. For use mix equal volumes of I and II. Ten c.c. of the mixed solution = 0.05 gramme glucose. For use in testing, 1 part of the mixed solution is diluted with about 3 parts water.

Ferric Chloride, $FeCl_3$. (1 in 10.) Neutral Ferric Chloride may be made by adding *dilute* ammonium hydroxide until a *faint* precipitate is obtained. Filter and use filtrate.

Ferric Ammonium Sulphate, $Fe(NH_4)(SO_4)_2.12H_2O$. U. S. P. (1 in 10).

Ferrous Sulphate, $FeSO_4.7H_2O$. (1 in 10.)

Fröhde's Reagent. 0.1 gramme of sodium molybdate in 10 c.c. of concentrated sulphuric acid.

Gastric Juice, Artificial. Add 0.3 gramme of pepsin to 100 c.c. of 0.3 p. c. hydrochloric acid.

Gold Chloride, $AuCl_3$. (1 in 30.)

Guaiac Mixture. 0.5 gramme gum guaiac in 10 c.c. alcohol with a few drops of copper sulphate (1–2000).

Günzberg's Reagent. Phloroglucin, 2 pts.; Vanillin, 1 pt.; Absolute Alcohol, 30 pts., by weight.

Haines' Solution. Dissolve 2 grammes pure $CuSO_4$ (crys.) in 15 c.c. of water, add 15 c.c. of pure glycerol and then 150 c.c. of 5 p. c. KOH solution. A clear dark-blue liquid should result.

Indigo-Carmine Solution. 1 gramme commercial indigo-carmine in 150 c.c. of water.

Iodine Test Solution. 1 gramme iodine, 3 grammes potassium iodide, in 50 c.c. water.

Lead Acetate, $Pb(C_2H_3O_2)_2.3H_2O$. (1 in 10.)

" " Basic. Use official, U. S. P. solution.

Litmus Test Solution. Exhaust powdered litmus with boiling alcohol. Digest residue in cold water, filter, and extract residue with boiling water. Filter and preserve the filtrate as a test solution. *Litmus paper* is prepared by impregnating unsized paper with the above solution.

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Lugol's Solution, (Liquor iodi compositus, U. S. P.) Iodine, 5 grammes, potassium iodide 10 grammes in 100 c.c. water.

Magnesia Mixture, U. S. P. 10 grammes $MgSO_4.7H_2O$ and 20 grammes NH_4Cl in 80 c.c. water. Add 42 c.c. ammonia water, U. S. P. Let stand several days, and filter.

Magnesium Chloride, $MgCl_2$. (1 in 10.)

" Sulphate, $MgSO_4.7H_2O$. Saturated solution, and 1 in 10.

Mayer's Solution, see mercuric potassium iodide.

Mercuric Chloride, $HgCl_2$. (1 in 20.)

" Potassium Iodide (Mayer's Solution), 1.344 grammes $HgCl_2$ dissolved in 60 c.c. of water; 5 grammes KI dissolved in 10 c.c. of water. Mix and dilute to 100 c.c.

Mercurous Nitrate, $2Hg_2(NO_3)_2 + H_2O$. (1 in 20.) Acidulate with nitric acid.

Methylene Blue and Eosin, see p. 203.

Methyl Orange. (Tropæolin D.) 1 gramme in 1000 c.c. of water. Add dilute sulphuric acid drop by drop, until liquid just turns red. Filter.

Millon's Reagent. 1 part mercury treated with 2 parts HNO_3 in the cold. Then heat on water-bath, dilute with 2 parts water, and after several hours, decant the clear liquid.

Naphthylamine Acetate Solution. See page 222.

Nessler's Reagent. See page 221.

Nylander's Reagent. See Almen-Nylander's Reagent.

Pavy's Solution. Copper sulphate, 3.465 grammes; Rochelle salt, 17 grammes; potassium hydroxide, 17 grammes. Dissolve in distilled water and make solution up to 100 c.c. Add 333 c.c. ammonium hydroxide, sp. gr. 0.88, and 396 c.c. water. For the test, use, undiluted, 50 c.c. of the solution. This will be reduced by 0.025 gramme of glucose.

Phenolphthalein. (Indicator.) 1 gramme in 100 c.c. dilute alcohol.

Platinic Chloride, $PtCl_4$. (1 in 10.) See page 39.

Potassium Carbonate, K_2CO_3. (1 in 10.)

" Chlorate, $KClO_3$. Crystals.

" Chromate, K_2CrO_4. (1 in 10.)

" Cyanide, KCN. (1 in 10.)

" Dichromate, $K_2Cr_2O_7$. (1 in 10.)

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Potassium Ferricyanide, $K_3Fe(CN)_6$. (1 in 10.)

" Ferrocyanide, $K_4Fe(CN)_6$. (1 in 10.)

" Hydroxide, KOH. U. S. P. 5 p. c. solution. Dissolve 60 grammes of KOH in 940 grammes of water.

" Hydroxide, *Alcoholic.* Dissolve 30 grammes of KOH in 20 c.c. of water, then add alcohol to 1000 c.c.

" Iodide, KI. (1 in 5.)

" Nitrate, KNO_3. Crystalline.

" Sulphate, K_2SO_4. (1 in 100.)

" Sulphocyanate, KCNS. (1 in 100.)

Purdy's Solution. Dissolve 4.742 grammes of $CuSO_4$ and 38 c.c. of glycerol in 200 c.c. of water. Dissolve 23.5 grammes of KOH in 200 c.c. of water. Mix the solutions and add 450 c.c. of ammonium hydroxide, sp. gr. 0.9, and then water to make 1000 c.c.

Schiff's Reagent. An aqueous solution of magenta (rosaniline-hydrochloride) decolorized by sulphur dioxide.

Silver Ammonium Nitrate. Dissolve 1 gramme of silver nitrate in 20 c.c. of water, then add dilute ammonia water until the precipitate first formed is nearly but not completely redissolved. Filter.

Silver Nitrate, $AgNO_3$. (1 in 50.)

Sodium Acetate, $NaC_2H_3O_2.3H_2O$. (1 in 10.)

" Carbonate, Na_2CO_3. Solid, and 1 in 10.

" Chloride, NaCl. Solution.

" Hydroxide, NaOH. U. S. P. 5 p. c. solution. 56 grammes dissolved in 944 grammes of water.

" Hydroxide, Alcoholic. Solution of NaOH in dilute alcohol.

" Hypobromite, NaBrO, for Urea test. 25 c.c. bromine added *slowly* to a solution of 100 grammes NaOH in 250 c.c. of water. The strong solution may be diluted with an equal volume of water.

" Hypochlorite, NaClO, for Urea test. See Chlorinated Soda.

" Nitroprusside, $Na_2FeNO(CN)_6. + 2H_2O$. Aqueous solution.

" Phosphate, $Na_2HPO_4.12H_2O$. (1 in 10.)

Stannous Chloride, $SnCl_2.2H_2O$. (1 in 10.) (Place a fragment of tin in the bottle.)

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Starch Test Solution. Triturate 1 gramme of starch with 10 c.c. cold water, then add boiling water, with constant stirring, to make 200 c.c.

Strontium Nitrate, $Sr(NO_3)_2$. Aqueous solution.

Sulphuretted Hydrogen. See Hydrosulphuric Acid.

Tanret's Solution. $HgCl_2$, 1.35 grammes; KI, 3.32 grammes; Acetic acid, 20 c.c. Distilled water to 100 c.c.

Uffelmann's Reagent. To 10 c.c. of 1 p. c. Phenol add 2 drops of neutral aqueous Ferric Chloride solution. The solution should be freshly prepared.

Uranium Nitrate, Standard Solution. See page 182.

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